Volume 30 OCTOBER, 1946 Number 10

BULLETIN
of the
American Association *of* Petroleum Geologists

CONTENTS

GEOLOGY OF MARACAIBO BASIN, VENEZUELA *By F. A. Sutton* 1621

ALGAE REEFS IN CAP ROCK OF OGALLALA FORMATION ON LLANO ESTACADO PLATEAU, NEW MEXICO AND TEXAS *By W. Armstrong Price, Maxim K. Elias, and John C. Frye* 1742

KINDERHOOK DOLOMITE OF SEDGWICK COUNTY, KANSAS *By W. A. Ver Wiebe* 1747

CORRELATION OF PALEOZOIC ROCKS ACROSS LAS ANIMAS ARCH IN BACA, LAS ANIMAS, AND OTERO COUNTIES, COLORADO *By John C. Maher* 1756

GEOLOGICAL NOTES

Alunite at Woodbine-Eagle Ford Contact in Northeastern Texas *By L. W. Stephenson* 1764

Preparation of Lantern Slides *By G. Zuloaga* 1771

REVIEWS AND NEW PUBLICATIONS

Recent Publications 1772

THE ASSOCIATION ROUND TABLE

Association Committees 1779

Membership Applications Approved for Publication 1782

Mid-Continent Regional Meeting, Wichita, Kansas, January 16-17, 1947 1784

West Texas Geological Society Field Trip, November 2 and 3 1785

MEMORIAL

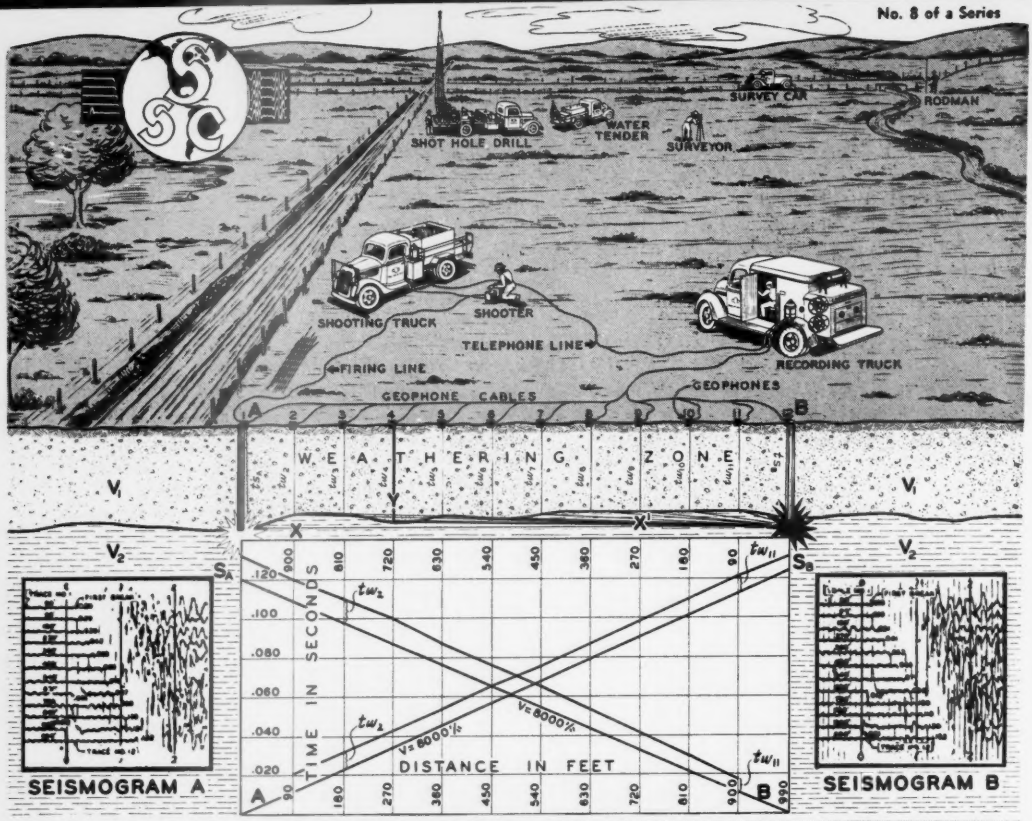
Otto Dreher *By E. A. Ritter* 1786

Donald Dudley Hughes *By Eric K. Craig* 1786

AT HOME AND ABROAD

Current News and Personal Items of the Profession 1789

COPYRIGHT, 1946, BY THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.



Accurate Interpretation Technique

The accuracy of Seismic interpretation is the only measure of its worth. This accuracy is dependent upon the full knowledge of all problems involved and the proper techniques necessary for their solution — a combination which can be acquired only by years of experience plus exceptional ability to recognize and solve these problems.

SSC presents to the oil industry more than 200 crew years of experience in accurate seismic interpretation. This experience helps to assure Oil Will Be Discovered.

Seismograph Service Corporation

TULSA, OKLAHOMA, U. S. A.

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OFFICE OF PUBLICATION, 708 WRIGHT BUILDING, TULSA, OKLAHOMA

GAYLE SCOTT, *Editor*

TEXAS CHRISTIAN UNIVERSITY, FORT WORTH 9, TEXAS

ASSOCIATE EDITORS

GENERAL	K. C. HEALD, Gulf Oil Corporation, Box 1166, Pittsburgh 30, Pa.
	HUGH D. MISER, U. S. Geological Survey, Washington 25, D. C.
	THERON WASSON, Pure Oil Company, 35 E. Wacker Drive, Chicago 1, Ill.
APPALACHIANS	RICHARD E. SHERRILL, University of Pittsburgh, Pittsburgh 13, Pa.
NORTH CENTRAL STATES	R. B. NEWCOMBE, Superior Oil Company, Grand Rapids, Mich.
KANSAS	EDWARD A. KOESTER, Darby and Bothwell, Inc., Wichita 2, Kan.
OKLAHOMA	
Western	ROBERT H. DOTT, Oklahoma Geological Survey, Norman, Okla.
Eastern	SHERWOOD BUCKSTAFF, Shell Oil Company, Inc., Box 1191, Tulsa 2, Okla.
TEXAS	
North and Central	J. B. LOVEJOY, Gulf Oil Corporation, Fort Worth 1, Tex.
Northeastern	C. I. ALEXANDER, Magnolia Petroleum Company, Tyler, Tex.
San Antonio	JOHN R. SANDIDGE, Magnolia Petroleum Company, San Antonio 5, Tex.
Permian Basin	E. RUSSELL LLOYD, Box 1026, Midland, Tex.
GULF COAST	SIDNEY A. JUDSON, Texas Gulf Producing Company, Houston 1, Tex.
	MARCUS A. HANNA, Gulf Oil Corporation, Houston 1, Tex.
EASTERN GULF	HENRY N. TOLER, Southern Natural Gas Company, Jackson, Miss.
ARKANSAS AND NORTH LOUISIANA	ROY T. HAZZARD, Gulf Refining Company of Louisiana, Shreveport 93, La.
ROCKY MOUNTAINS	A. E. BRAINERD, Continental Oil Company, Denver 2, Colo.
CALIFORNIA	W. D. KLEINPELL, Box 1131, Bakersfield, Calif.
	E. R. ATWILL, Union Oil Company of California, 617 W. 7th, Los Angeles 14
CANADA	THEODORE A. LINK, Imperial Oil Limited, Toronto, Ontario
SOUTH AMERICA	HOLLIS D. HEDBERG, Mene Grande Oil Co., Apt. 709, Caracas, Venezuela

THE BULLETIN is published by the Association on the 15th of each month.

EDITORIAL AND PUBLICATION OFFICE AND ASSOCIATION HEADQUARTERS, 708 Wright Building, 115 and 117 West Third Street, Tulsa, Oklahoma. Post Office, Box 979, Tulsa 1.

BRITISH AGENT: Thomas Murby & Co., 40 Museum Street, London, W. C. 1.

SUBSCRIPTION PRICE to non-members is $15 per year (separate numbers, $1.50), prepaid to addresses in the United States; outside the United States, $15.40.

CLAIMS FOR NON-RECEIPT must be sent within 3 months of date of publication, to be filled gratis.

BACK NUMBERS, if available, may be ordered from Headquarters. Price list on request.

	Mem.	*Non-Mem.*
Cloth-bound Bulletin, Vols. 12 (1928)–15 (1931) incl., each	$5.00	$ 6.00

SPECIAL PUBLICATIONS	*Mem.*	*Non-Mem.*
1936. Geology of Tampico Region	3.50	4.50
1936. Map of Southern California	.50	.50
1938. Miocene Stratigraphy of California	4.50	5.00
1941. Stratigraphic Type Oil Fields	4.50	5.50
1944. Tectonic Map of United States	2.00	2.00

Communications about the Bulletin, manuscripts, editorial matters, subscriptions, special rates to public and university libraries, publications, membership, change of address, advertising rates, and other Association business should be addressed to

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

J. P. D. HULL, BUSINESS MANAGER

BOX 979, TULSA 1, OKLAHOMA

Entered as second-class matter at the Post Office at Tulsa, Oklahoma, and at the Post Office at Menasha, Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

Organized at Tulsa, Oklahoma, February 10, 1917, as the Southwestern Association of Petroleum Geologists. Present name adopted, February 26, 1918. Incorporated in Colorado, April 23, 1924. Domesticated in Oklahoma, February 9, 1925.

OFFICERS FOR THE YEAR ENDING MARCH, 1947

EARL B. NOBLE, *President*, Los Angeles, California
EDWARD A. KOESTER, *Secretary-Treasurer*, Wichita, Kansas
D. PERRY OLCOTT, *Vice-President*, Houston, Texas
GAYLE SCOTT, *Editor*, Fort Worth, Texas

The foregoing officers, and the *Past-President*, MONROE G. CHENEY, Coleman, Texas, constitute the Executive Committee.

DISTRICT REPRESENTATIVES (Terms expire after annual meetings of years shown in parentheses)

Amarillo: Elisha A. Paschal (48), Amarillo, Tex.
Appalachian: W. O. Ziebold (47), Charleston, W. Va.
Canada: Edwin H. Hunt (47), Calgary, Alberta
Capital: Carl H. Dane (48), Washington, D. C.
Corpus Christi: Ira H. Stein (47), Alice, Tex.
Dallas: W. Dow Hamm (48), Dallas, Tex.
East Oklahoma: J. L. Borden (47), Glenn D. Hawkins (47), Frank R. Clark (48), Tulsa; Robert L. Kidd (48), Bartlesville
Fort Worth: Lynn K. Lee (47), Fort Worth, Tex.
Great Lakes: Robert M. English (47), Mattoon, Ill. Stanley G. Elder (48), Evansville, Ind.
Houston: A. P. Allison (47), P. B. Leavenworth (47), Ira H. Brinkerhoff (48), Shirley L. Mason (48), P. H. O'Bannon (48), Houston, Tex.
Michigan: E. J. Baltrusaitis (47), Saginaw, Mich.
New Mexico: Georges Vorbe (47), Socorro, N. Mex.
New York: Gail F. Moulton (47), New York City
Pacific Coast: Rollin Eckis (47), Glenn C. Ferguson (47), Bakersfield, Calif.; Frank W. Bell (48), Sacramento; Claude E. Leach (48), Ventura; D. E. Taylor (48), Long Beach
Rocky Mountains: Robert L. Sielaff (47), Casper, Wyo.; H. E. Christensen (48), Denver, Colo.
Shreveport: G. D. Thomas (47), Shreveport, La.
South America: L. W. Henry (47), Caracas, Venezuela
Southeast Gulf: Henry N. Toler (47), Jackson, Miss.
Southern Louisiana: Max Bornhauser (47), Lafayette
So. Permian Basin: George R. Gibson (47), Warren D. Anderson (48), Midland, Tex.
South Texas: Adolph Dovre (47), Wesley G. Gish (48), San Antonio
Tyler: J. S. Hudnall (47), Tyler, Tex.
West Oklahoma: Jerry B. Newby (47), Oklahoma City: C. W. Tomlinson (48), Ardmore
Wichita: John W. Inkster (47), Wichita, Kan.
Wichita Falls: J. J. Russell, Jr. (48), Wichita Falls, Tex.

DIVISION REPRESENTATIVES

Paleontology and Mineralogy: F. W. Rolshausen (47), Houston, Texas; Henryk B. Stenzel (47), Austin, Texas

PACIFIC SECTION (Chartered, March, 1925)

E. R. ATWILL, *President*, Union Oil Company of California, 617 W. 7th Street, Los Angeles, California
VINCENT W. VANDIVER, *Vice-President*, Seaboard Oil Company, 417 S. Hill Street, Los Angeles 13
ASHLY S. HOLSTON, *Secretary-Treasurer*, Tide Water Assoc. Oil Company, 801 Pacific Electric Bldg., Los Angeles
Membership restricted to members of the Association in good standing, residing in Pacific Coast states. Dues: $2.00 per year.

SOUTH TEXAS SECTION (Chartered, April, 1929)

THORNTON DAVIS, *President*, Peerless Oil and Gas Co., 2023 Alamo National Building, San Antonio, Texas
PAUL B. HINYARD, *Secretary-Treasurer*, Shell Oil Co., 2000 Alamo National Building, San Antonio, Texas
Membership limited to persons eligible to Association membership. Dues: $2.50. Annual meeting in October.

EASTERN SECTION (Chartered, April, 1946)

GAIL F. MOULTON, *President*, Chase National Bank, 18 Pine Street, New York, N.Y.
L. G. WEEKS, *Secretary*, Standard Oil Company (N. J.), Room 2150, 30 Rockefeller Plaza, New York, N.Y.
Membership restricted to members of the Association in good standing, residing in New York district.

DIVISION OF PALEONTOLOGY AND MINERALOGY
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

(Organized, March, 1927; affiliated, March, 1928; chartered, technical division, April, 1930)

F. W. ROLSHAUSEN, *President*, Humble Oil and Refining Company, Houston, Texas
HENRYK B. STENZEL, *Secretary-Treasurer*, Bureau of Economic Geology, Austin 12, Texas

SEND DUES, SUBSCRIPTIONS AND ORDERS FOR BACK NUMBERS TO BOX 979, TULSA 1, OKLAHOMA. The Society and the Paleontological Society jointly issue six times a year the *Journal of Paleontology*, J. Marvin Weller, University of Chicago, Chicago 37, Illinois, and C. Wythe Cooke, U. S. National Museum, Washington, D. C., editors: subscription, $6.00. The *Journal of Sedimentary Petrology*, W. H. Twenhofel, editor, University of Wisconsin, Madison, Wisconsin, is issued three times a year: subscription, $3.00. Single copies, *Journal of Paleontology*, $2.00; *Journal of Sedimentary Petrology*, $1.50. Society dues: with *Jour. Pal.*, $5.00; with *Jour. Sed. Petrology*, $3.00; with both, $8.00 per year.

AFFILIATED SOCIETIES (Dates of affiliation in parentheses)

Alberta Society of Petroleum Geologists, Calgary, Alberta, Canada (31). W. P. Hancock, Secy. Imperial Oil Ltd., 339 7th Av. W.
Appalachian Geological Society, Charleston, W. Virginia (31). R. L. Alkire, Secy., 605 Union Building
Ardmore Geological Society, Ardmore, Oklahoma (36). Ben S. Curtis, Secy., Independent, Box 156
Corpus Christi Geological Society, Corpus Christi, Texas (43). O. G. McClain, Secy., Consultant, 224 Nixon Building
Dallas Geological Society, Dallas, Texas (35). John M. Clayton, Secy., Seaboard Oil Co., 1400 Continental Bldg.
East Texas Geological Society, Tyler, Texas (32). B. F. Murphy, Secy., Amerada Petroleum Corporation, Box 2026
Fort Worth Geological Society, Fort Worth, Texas (31). S. K. Van Steenbergh, Secy., Sinclair Prairie Oil Co., 901 Fair Bldg.
Houston Geological Society, Houston, Texas (32). A. F. Childers, Secy., Gulf Oil Corporation, Box 2100
Illinois Geological Society (39). John B. Patton, Secy., Magnolia Petroleum Company, Box 535, Mt. Vernon
Indiana-Kentucky Geological Society (38). F. H. Latimer, Secy., Sun Oil Company, Evansville, Ind.
Kansas Geological Society, Wichita, Kansas (31). F. E. Mettner, Secy., Transwestern Oil Co., 605 Union Natl. Bank Bldg.
Michigan Geological Society (37). Charles K. Clark, Secy., Pure Oil Co., 402 Second National Bank Bldg., Saginaw
Mississippi Geological Society, Jackson, Miss. (41). H. L. Spyres, Secy., Skelly Oil Company
New Orleans Geological Society, New Orleans, La. (43). Philip R. Allin, Secy., Gulf Refining Company, Harvey, La.
North Texas Geological Society, Wichita Falls, Texas (38). Turner Wynn, Secy., Stanolind Oil and Gas Company
Oklahoma City Geological Society, Oklahoma City, Okla. (31). Frederick H. Kate, Secy., Shell Oil Company, Inc.
Panhandle Geological Society, Amarillo, Texas (32). A. R. Erickson Secy., Phillips Petroleum Company
Shawnee Geological Society, Shawnee, Oklahoma (31). Marcelle Mousley, Secy., Atlantic Refining Company, Box 169
Shreveport Geological Society, Shreveport, Louisiana (32). J. Ed. Lytle, Secy., Union Producing Company
Society of Exploration Geophysicists (32). George E. Wagoner, Secy., Carter Oil Company, Shreveport, Louisiana
South Louisiana, Geological Society, Lake Charles, La. (37). Lloyd D. Traupe, Secy., Ohio Oil Company
Southeastern Geological Society, Tallahassee, Fla. (44). H. A. Sellin, Secy., Magnolia Petroleum Co., Box 1198
Tulsa Geological Society, Tulsa, Oklahoma (31). John R. Crain, Secy., Ashland Oil and Refining Company
West Texas Geological Society, Midland, Texas (38). Charles A. Shaw, Secy., Forest Oil Corporation, Box 366
Wyoming Geological Association, Box 545, Casper (45). David T. Hoenshell, Secy., General Petroleum Corporation
Yellowstone-Bighorn Research Association, Inc. (44). W. T. Thom, Jr., Secy., Princeton, N. J.

HALOID RECORD

SEISMOGRAPH RECORDING PAPER IS FAVORED BY CRITICAL GEOPHYSICISTS

HALOID RECORD is plenty tough. It resists heat and withstands moisture. It provides sharp lines and legible contrast. Its processing advantage and consistently uniform performance even under the most adverse conditions of field and laboratory, make it the ideal paper for this work.

For superior seismographic recordings that successfully combine photographic excellence with an amazing ability to withstand abuse, use Haloid Record—the paper that's favored by critical geophysicists.

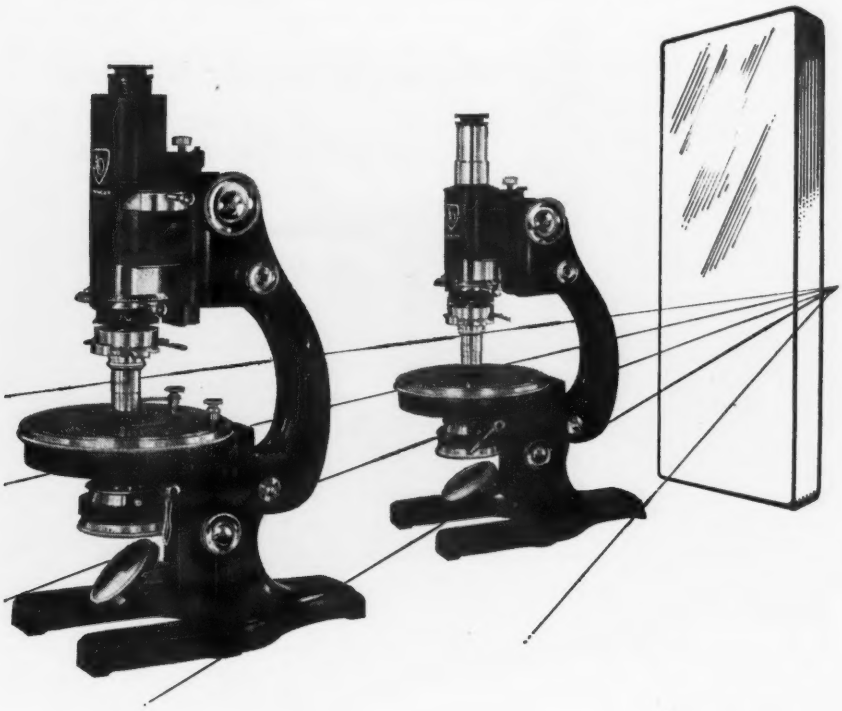
THE HALOID COMPANY
459 Haloid St., Rochester 3, N. Y.

HEAVENLY BODIES ARE VISIBLE...

And favorable oil areas can practically become so with the aid of dependable Gravity Meter Surveys. Accurate surveys, soundly interpreted, give reliable data on which to base YOUR decisions. The Mayes-Bevan organization, fully qualified, with modern up-to-date equipment, is ready to help you with your oil exploration problems.

MAYES-BEVAN COMPANY
GRAVITY METER SURVEYS
M B

KENNEDY BLDG TULSA, OKLAHOMA



A MILESTONE PASSED

With their adoption of a newly-perfected Polaroid* unit to replace costly calcite prisms, these two Spencer Polarizing Microscopes have passed a long-sought milestone in instrument design.

In addition to making lower prices possible, the new units provide better contrast of image and crispness of interference figures. Comparing favorably with calcite in all other respects, they have won the approval of outstanding petrographers.

Spencer Polarizing Microscope No. 42 meets nearly every requirement of the geologist, mineralogist, chemist, biologist, and instructor. No. 43 is designed for teaching and advanced chemical microscopy. Other models, equipped with calcite prisms, are available.

For complete details, write Dept. K29.

American Optical
COMPANY
Scientific Instrument Division
Buffalo 11, New York

*Product of the Polaroid Corporation.

Manufacturers of **SPENCER** *Scientific Instruments*

Schlumberger Integrated Well Service
Saves Costly Rig Time
1 TRIP TO THE WELL...
RADIO ACTIVE DEPTH MARKER
SIDEWALL CORING
DIRECTIONAL SURVEYS
DIPMETER SURVEYS
ELECTRICAL WELL LOGGING
Call SCHLUMBERGER for YOUR next GUN PERFORATING job — too.
SCHLUMBERGER
SCHLUMBERGER WELL SURVEYING CORPORATION • HOUSTON • TEXAS

Bulletin Advertisers

Advanced Exploration Company xlvii
Aero Service Corporation xxii
American Optical Company v
American Paulin System xxvi

Baker Oil Tools, Inc. xxxv
Baroid Sales Division xxix
Barret, William M., Inc. xxiii

Dowell Incorporated .....

Eastman Oil Well Surveys xix
Economic Geology Publishing Company xxii
Exploration Geophysics xlii

Fairchild Aerial Surveys xliii
Federal Electric Company xxxi
First Natl. Bank and Trust Co. of Tulsa xix
C. H. Frost Gravimetric Surveys xlv

General Geophysical Company xxviii
Geophysical Service, Inc. viii
Geotechnical Corporation xix
Gravity Meter Exploration Company xli
Gulf Publishing Company xlviii

Haloid Company iii
Heiland Research Corporation xxxvi
Hercules Powder Company, Inc. .....
Hughes Tool Company .....Cover iv

Independent Exploration Company xl

Journal of Geology xxii
Journal of Paleontology .....
Journal of Sedimentary Petrology .....

Keystone Exploration Company xxvii
Koenig Iron Works xliv

Lane-Wells Company xxv
Lufkin Rule Company xlii

Mayes-Bevan Company iv

North American Geophysical Company xxxv

Petty Geophysical Engineering Company xxxviii

Reed Roller Bit Company .....Cover iii
Robert H. Ray Co. xxxii
Rogers-Ray, Inc. xxxiii

Schlumberger Well Surveying Corporation vi
Seismic Engineering Company .....
Seismic Explorations, Inc. xxxiv
Seismograph Service Corporation ..Cover ii
Society of Exploration Geophysicists .....
Southern Geophysical Company xxxix
Sperry-Sun Well Surveying Company xxxvii
Sullivan Division, Joy Mfg. Co. ....xx-xxi

Thompson Tool Company, Inc. .....
Triangle Blue Print and Supply Company..

United Geophysical Company xxiv
Universal Exploration Company xlv

Western Geophysical Company xxx

PROFESSIONAL CARDS

Alabama ix
California ix
Colorado ix
Illinois x
Indiana x
Kansas x
Louisiana x
Mississippi x
New York x
North Carolina xi
Ohio xi
Oklahoma xi
Pennsylvania xii
Texas .....xii, xiii, xiv, xv
West Virginia xv
Wyoming xv

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

Appalachian xviii
Ardmore xvii
Corpus Christi xvii
Dallas xvii
East Texas xvii
Exploration Geophysicists xviii
Fort Worth xvii
Houston xviii
Illinois xvi
Indiana-Kentucky xvi
Kansas xvi
Michigan xvi
Mississippi xvi
New Orleans xvi
North Texas xviii
Oklahoma City xvii
Rocky Mountain xv
Shawnee xvii
Shreveport xvi
Southeastern xv
South Louisiana xvi
South Texas xviii
Tulsa xvii
West Texas xviii
Wyoming xviii

Articles for November *Bulletin*

West Edmond Oil Field, Central Oklahoma *By D. A. McGee and H. D. Jenkins*

Correlation of Permian of West Texas and Southeast New Mexico *By John W. Skinner*

Normal Fault Structures and Others *By Bailey Willis*

Faulting in East Part of Grand Canyon of Arizona *By C. E. Van Gundy*

Spectrochemical Sample Logging of Limestones *By L. L. Sloss and S. R. B. Cooke*

Seismograph Surveys
GSI
GEOPHYSICAL SERVICE INC.
DALLAS, TEXAS

Volume 30 Number 10

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OCTOBER, 1946

GEOLOGY OF MARACAIBO BASIN, VENEZUELA[1]

F. A. SUTTON[2]
Caracas, Venezuela

ABSTRACT

The Maracaibo basin lies mainly in northwestern Venezuela and occupies the V-shaped depression between the diverging Andes de Mérida and Sierra de Perijá, two offshoots of the main Cordilleran system of South America. On the southwest the basin extends slightly into eastern Colombia.

The area of the basin is approximately 61,450 square kilometers (23,572 square miles), of which about 12,900 square kilometers (5,000 square miles) are covered by Lake Maracaibo, a large body of brackish water whose outlet is into the Caribbean Sea by way of the Gulf of Venezuela. Large areas surrounding the lake are covered by swamps and heavily wooded flats and nowhere within the basin proper is the elevation more than 100 meters (328 feet).

The presence of oil in the Maracaibo basin has been known for centuries, but it was not until the years immediately preceding the first World War that the major oil companies took an active interest in the area. The Shell Company led the way and in 1914 discovered the Mene Grande field, east of Lake Maracaibo. During the next 2 years the same company discovered the Río de Oro and Las Cruces (Tarra) fields, southwest of the lake, and in 1917 drilled the discovery well of the Bolívar Coastal field. This company's success aroused the interest of others and it was not long until most of the major American oil companies and a number of independents were active in western Venezuela. At the present time only the Creole Petroleum Corporation (Standard Oil Company (New Jersey)), the Shell Group, the Mene Grande Oil Company (Gulf Oil Corporation), the Orinoco Oil Company (Pure Oil Company), and the Richmond Exploration Company (Standard Oil of California) are active in the Venezuelan part of the basin, while the Colombian Petroleum Company (Socony Vacuum-Texas) is active in the Colombian part.

About 85 per cent of the basin floor is covered by the waters of Lake Maracaibo and recent deposits, but the bordering highlands expose a geologic section extending from the pre-Cambrian to Recent. The Ordovician, Devonian, Permo-Carboniferous, and Triassic were periods of rather widespread deposition, but each was followed by a long interval of uplift and erosion so that only remnants of the original deposits are now present in the uplifted areas.

The pre-Cambrian is represented by the igneous and metamorphic rocks of the Perijá and Iglesias series, which form the cores of the bordering mountain ranges. These are followed by the largely metamorphosed Mucuchachí series of Upper Cambrian to Upper Ordovician age. The Devonian is well developed in the Sierra de Perijá, where more than 2,438 meters (8,000 feet) of the fossiliferous sediments of the Cachirí group are exposed along the Río Cachirí. The Palmarito series of the Permo-Pennsylvanian is distributed extensively throughout the Mérida Andes and along the eastern slopes of the Sierra de Perijá. The greatest thickness is in the type area of the Mérida Andes, where 1,800 meters (5,910 feet) have been measured. The redbeds of the Upper Triassic La Quinta formation are generally limited to the mountain regions and are best developed in Táchira and Mérida, where thicknesses up to 3,500 meters (11,482 feet) have been noted.

[1] Read before the Association at Chicago, April 3, 1946. Published by permission of the Creole Petroleum Corporation.

[2] Geologist, Creole Petroleum Corporation.

Rocks of Cretaceous age are distributed widely around the margin of the basin. The Lower Cretaceous is represented by the thick sandstones and conglomerates of the Río Negro formation and has a limited distribution in the west central part of the District of Perijá, Zulia. The Middle Cretaceous is marine in origin and has an over-all average thickness of about 700 meters (2,297 feet). Its component formations are the Apón, Aguardiente, and Capacho, all of which are distributed widely throughout the basin. The Apón formation, formerly included in the Cogollo, is defined here for the first time. The Upper Cretaceous has an average over-all thickness of about 650 meters (2,133 feet). It is largely of marine origin and comprises the La Luna, Colón, Mito Juan, and Catatumbo formations.

The Paleocene is represented by the shallow marine sediments of the Guasare formation, which has an average thickness of 400 meters (1,312 feet) and occupies a limited belt extending southeastward across the northern part of the basin.

The Eocene sequence, which is largely of marine origin, has an over-all thickness in excess of 3,700 meters (12,140 feet). Its component members are distributed widely throughout the basin and comprise the Marcelina, Misoa, Paují, Ambrosio, and equivalent formations.

The post-Eocene Tertiary section has a thickness exceeding 1,600 meters (5,249 feet). The fresh-water and terrestrial deposits of the Oligocene El Fausto, and the equivalent Icotea formation, have a limited areal distribution. The La Rosa and Lagunillas formations of the Lower and Middle Miocene are largely of marine and brackish-water origin and, with their equivalents, are distributed widely throughout the area. The Betijoque formation of the Upper Miocene and Cerro Vigía formation of the Pliocene are fresh-water and terrestrial deposits. The former has a rather extensive distribution but the latter is limited to the northwestern part of the basin.

At one place or another within the basin, commercial accumulation of oil has been discovered in all but two of the seventeen formations comprising the geologic section which extends from the base of the Middle Cretaceous to the top of the Middle Miocene. This sequence has an over-all thickness in excess of 7,000 meters (23,000 feet).

Numerous oil seepages and asphalt deposits are present around the edges of the basin and along the crests of truncated anticlines where the Cretaceous and Eocene sediments crop out.

The Maracaibo basin occupies the structural depression which resulted from the uplift of the bordering Mérida Andes and Sierra de Perijá. It has been subjected to the recurrent Andean orogenies which began at the close of the Eocene and culminated in the late Pleistocene when the ranges were elevated to their present heights and the basin received its present outline. Throughout a long part of Oligocene time the area remained above sea-level and was severely eroded. The major unconformity of the post-Cretaceous is along this break.

A number of structural trends, parallel and subordinate to the bordering highlands, are present along the eastern and western flanks, and it is along these that the outlying oil fields of the basin are located. The Bolívar Coastal field, largest in the area and outstanding among the major oil fields of the world, occupies a position on the lakeward-dipping northeastern limb of the basin. The structure is monoclinal and the post-Eocene sediments are deposited on the eroded and partially peneplaned Eocene surface, which was tilted gently to the southwest in late Pleistocene time. The oil in the post-Eocene sediments represents updip shore-line accumulation, controlled largely by the type of sedimentation. Accumulation in the underlying Eocene may be either stratigraphic or structural.

At the present time there are thirteen active fields in the basin. Eight of these are located in Venezuela and five in Colombia. In 1945 the total production for all fields was 221,730,000 barrels, approximately 9 per cent of the reported world total. On December 31, 1945, the cumulative total production was 2,634,430,000 barrels.

The Bolívar Coastal field produced 186,861,000 barrels during 1945 and, on December 31, 1945, had a total cumulative production of 2,188,339,000 barrels.

The total remaining proved reserves of the basin are estimated to be in excess of 5,500,000,000 barrels.

Introduction

The presence of oil in the Maracaibo basin has been known for many years. According to the accounts of some historians, the buccaneers of the 16th and 17th centuries used the quiet waters on Lake Maracaibo as a hide-out where they could recuperate from their strenuous engagements and at the same time calk the seams of their ships with the pitch and asphalt occurring plentifully near the shores of the lake.

The basin lies mainly in the extreme northwestern part of Venezuela and occupies the depression between the diverging Andes de Mérida and Sierra de

Perijá, two offshoots of the main Cordilleran system of South America. On the southwest the basin extends slightly into eastern Colombia (Fig. 1).

Venezuela lies along the north coast of South America on the Caribbean Sea, with Colombia on the west, British Guiana on the east, and Brazil on the south. It is one of the major oil countries of the world and the Maracaibo basin has accounted for 82 per cent of the country's total production.

In the early years of the present century unsuccessful attempts were made to exploit the large asphalt deposit at Inciarte, about 72 kilometers (45 miles) west of Maracaibo city, but not until shortly before the first World War did the major oil companies become actively engaged in exploring for oil. The Shell Company led the way, and in 1914 discovered the Mene Grande field east of Lake Maracaibo on concessions held by the Barber Asphalt Company. During the next 2 years the same company discovered the Río de Oro and Las Cruces (Tarra) fields in the Colón district southwest of the lake, and in 1917 drilled the discovery well of the Bolívar Coastal field. Shell's success aroused the interest of others, and it was not long until most of the major American oil companies and a number of independents were active in western Venezuela. Some were successful and some were not, while others turned their holdings over to the larger companies to operate. At the present time only the Creole Petroleum Corporation (Standard Oil Company (New Jersey)), the Shell Group, the Mene Grande Oil Company (Gulf Oil Corporation), the Orinoco Oil Company (Pure Oil Company), and the Richmond Exploration Company (Standard of California) are operating in the Venezuelan part of the basin, while the Colombian Petroleum Company (Socony Vacuum-Texas) operates in the Colombian part. The Richmond Company entered the area after the passage of the present Venezuelan Petroleum Law in 1943, and is carrying out an extensive exploration program.

This paper is essentially a compilation of the work of others. The writer has had free access to the geologic files of the Creole Petroleum Corporation, which cover a period extending over the past 30 years, and is grateful to the many geologists who have contributed their share toward the building up of those files. Members of Creole's present geologic staff have assisted the writer in many ways and special acknowledgment is due K. F. Dallmus for his many helpful suggestions and A. N. Dusenbury for his many contributions to the paleontology and careful review of the stratigraphy. A. A. Olsson kindly furnished the plates of fossils and is largely responsible for the Cretaceous paleontology.

The paper was prepared at the request of the American Association of Petroleum Geologists, and the writer undertook the assignment at the suggestion of G. Zuloaga, manager of Creole's exploration department.

Physiography

The topographic expression of the Maracaibo basin area embraces four major provinces (Fig. 2): the Sierra de Perijá, the Andes de Mérida (Venezuelan Andes), the Serranía de Trujillo, and the Maracaibo basin.

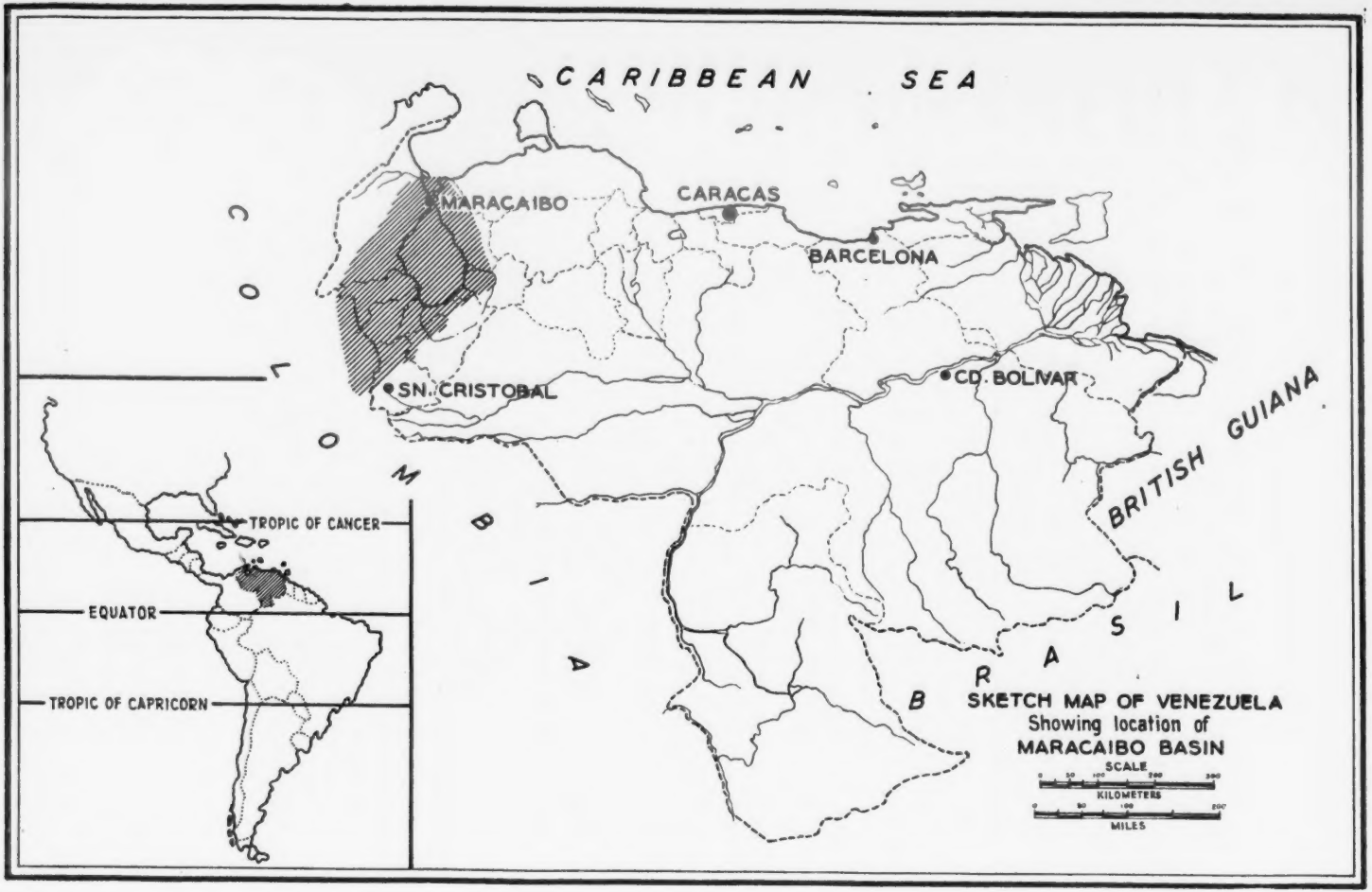

CARIBBEAN SEA
MARACAIBO
CARACAS
BARCELONA
SN. CRISTOBAL
CD. BOLIVAR
BRITISH GUIANA
COLOMBIA
BRASIL
TROPIC OF CANCER
EQUATOR
TROPIC OF CAPRICORN
SKETCH MAP OF VENEZUELA
Showing location of
MARACAIBO BASIN
SCALE
KILOMETERS
MILES

FIG. 1

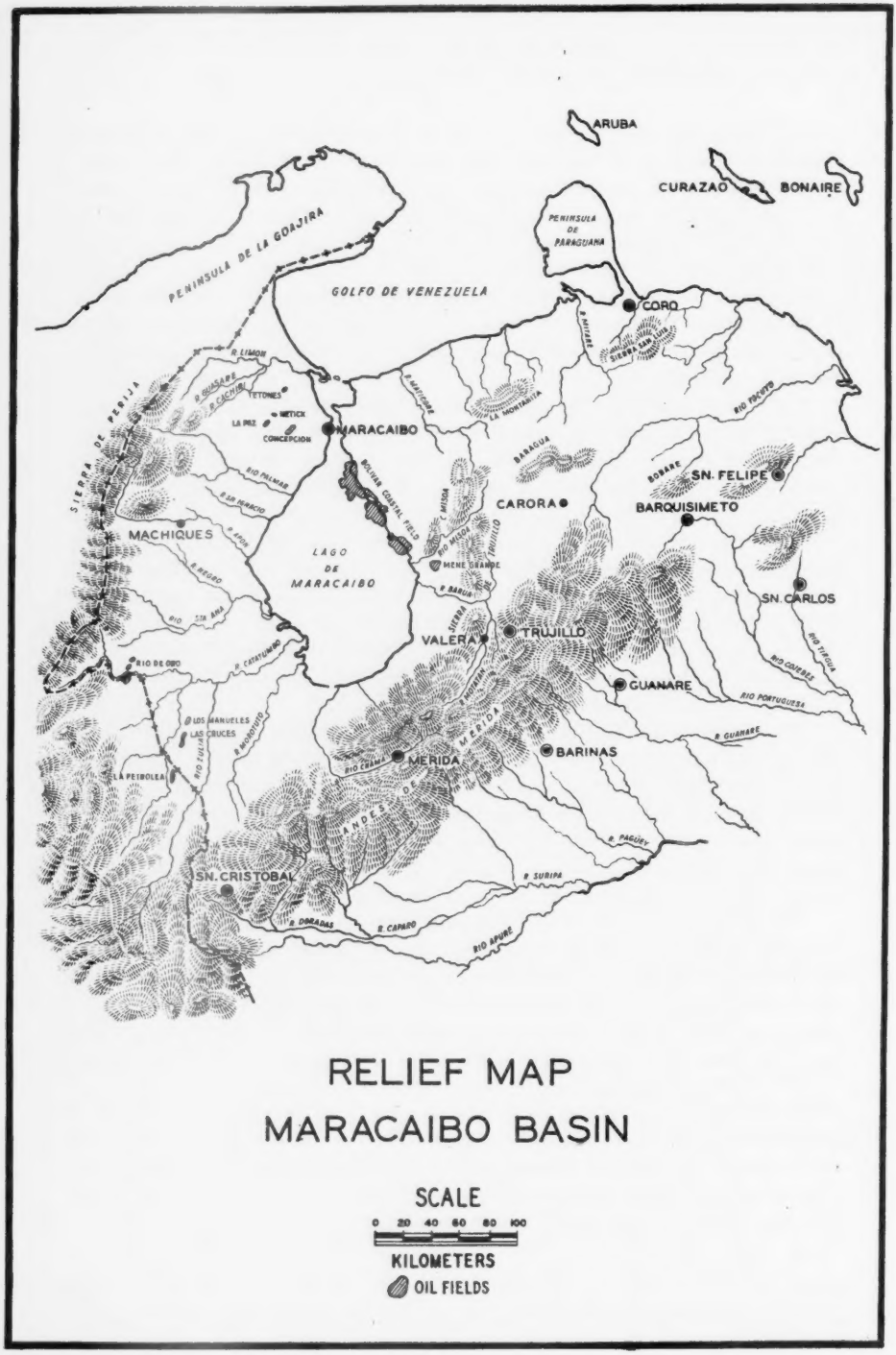
The Sierra de Perijá, a continuation of the Cordillera Oriental of eastern Colombia, trends in a northerly direction along the Colombian-Venezuelan border. In Colombia, the Cordillera attains its maximum elevation east of Cocuy, from which point it descends in a short distance to the Catatumbo Gap near the boundary with Venezuela. From this low area, where elevations drop to 1,500 meters (4,921 feet), the Sierra de Perijá rises and attains elevations approaching 3,750 meters (12,303 feet) in the western part of the District of Perijá, Zulia. Farther north, in the District of Maracaibo, the range begins a general northward decline and becomes progressively lower until its abrupt termination against the eastward-trending Ocoa fault.

The Andes de Mérida (Venezuelan Andes) branch from the Cordillera Oriental southwest of San Cristóbal and trend northeasterly through the states of Táchira, Mérida, and Trujillo. The range loses its identity as a major topographic unit in the southern and central parts of the State of Lara. Beyond Barquisimeto it is succeeded by the eastward-trending Coast Range. Shortly after its divergence from the Cordillera Oriental, the range exhibits a structural and topographic depression, the Táchira Gap, which during periods of past sedimentation formed a connection between the Maracaibo basin and the southward-lying Llanos basin. From the Táchira Gap, where elevations range from 150 to 950 meters (492 to 3,117 feet) the range rises in a relatively short distance and attains its maximum elevation of 5,003 meters (16,414 feet) in the "snow peaks" of Mérida. From here the decline is gradual into southern Lara.

The Serranía de Trujillo branches from the Mérida Andes in northern Mérida and passes northward into western Lara, where it assumes an arcuate curve westward before crossing the eastward-trending Maracaibo arch. Immediately north of the arch the range swings abruptly eastward and follows this course throughout the State of Falcón. Elevations in the Serranía de Trujillo range from 300 to 1,200 meters (984 to 3,937 feet). They may be considerably greater in western Lara, which is one of the least explored areas of Venezuela.

The Maracaibo basin, which is a structural as well as topographic basin, occupies the V-shaped depression lying between the diverging Sierra de Perijá and Andes de Mérida. It extends from near Cúcuta in eastern Colombia northward to the Gulf of Venezuela, a distance of 380 kilometers (236 miles) and has a maximum width of 240 kilometers (149 miles). Its area is approximately 61,450 square kilometers (23,572 square miles). In Venezuela the basin lies almost entirely within the State of Zulia and, in Colombia, occupies a small part of eastern Santander del Norte. The general relief is very low. The northeastern part is covered largely by Lake Maracaibo, a large body of fresh to brackish water whose outlet is into the Gulf of Venezuela through the narrow Strait of Maracaibo. The area of the lake, including Tablazo Bay, is approximately 12,900 square kilometers (5,000 square miles) and its maximum depth is 40 meters (131 feet). Large areas surrounding the lake, especially on the south and southwest, are covered by swamps and heavily wooded flats. Nowhere in the basin proper is the

FIG. 1



RELIEF MAP
MARACAIBO BASIN

SCALE

0 20 40 60 80 100

KILOMETERS

OIL FIELDS

FIG. 2

elevation more than 100 meters (328 feet) and this only along the foothills of the bordering highlands.

The drainage pattern is simple. All streams flow into Lake Maracaibo. The major carriers occur in the southwestern part of the basin. They head in the Sierra de Perijá and meander eastward and northeastward across the low, flat swamp lands and jungle-covered areas which border the lake. The streams are heavily silt-laden and delta-forming. Principal among these are the Ríos Catatumbo, Santa Ana, Escalante, Chama, and their many tributaries.

Northward along the western side of the basin the only perennial streams of importance are the Río Palmar, which traverses the District of Urdaneta, and the Río Limón which forms the boundary between the districts of Mara and Paez, Zulia. Principal tributaries of the latter are the Ríos Guasare, Socuy, and Cachirí.

On the east and southeast, the area between the lake and the bordering mountains is relatively narrow. The traversing streams are short and fast-flowing and have few tributaries. The principal streams are the Ríos Misoa, Motatán, and Torondoy.

STRATIGRAPHY

Rocks ranging in age from probable pre-Cambrian time to Recent are exposed within the Maracaibo basin, although the geologist in his search for oil has paid scant attention to the non-petroliferous strata of the Paleozoic and early Mesozoic eras. The Ordovician, Devonian, Permo-Carboniferous, and Triassic were periods of rather widespread deposition, but each was followed by a long interval of uplift and erosion so that only remnants of the original deposits are now present in the uplifted areas. These are considered briefly in the following discussion, but greater space has been devoted to the younger part of the section containing the petroliferous formations.

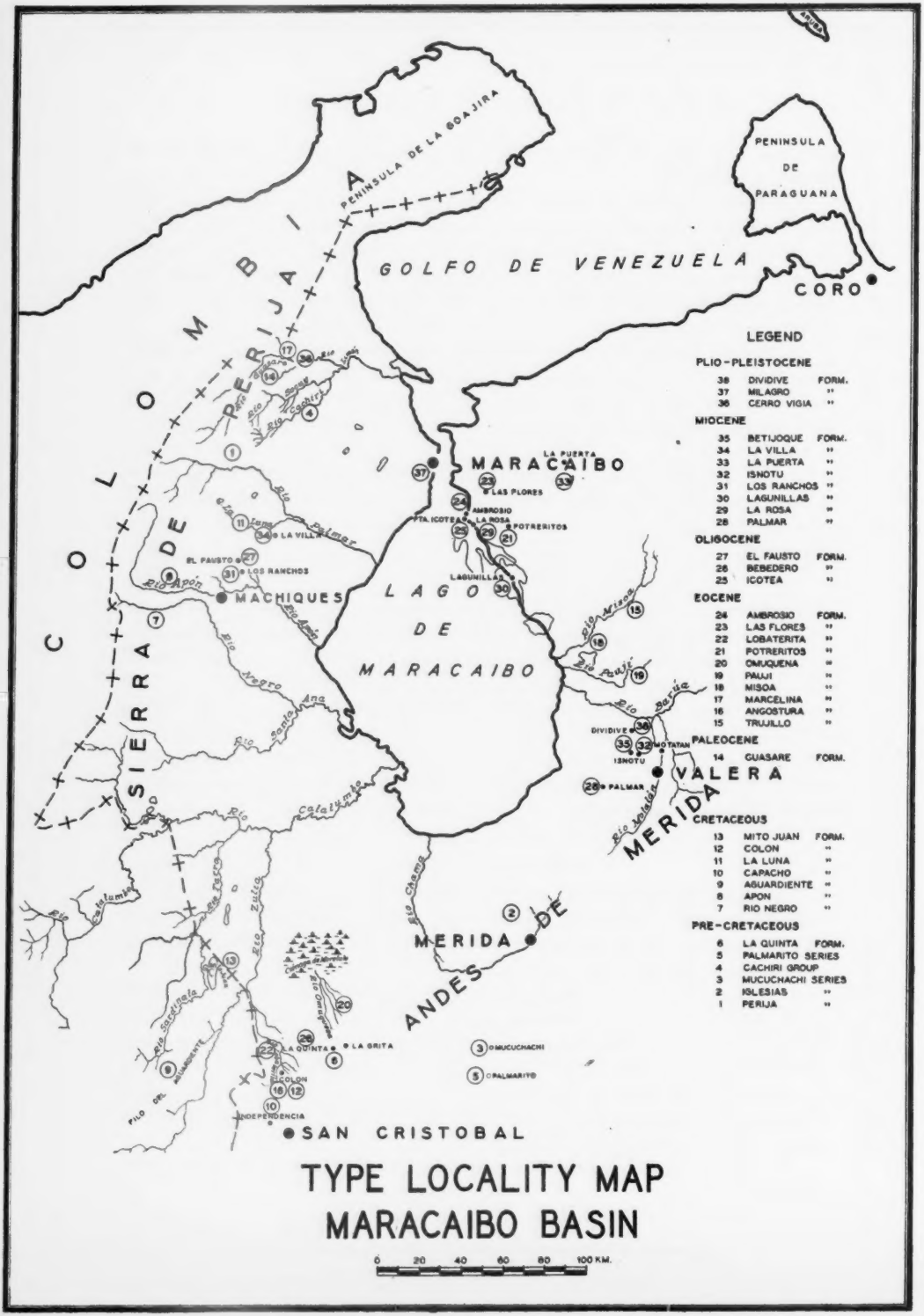
PRE-CAMBRIAN

PERIJÁ SERIES (PRE-CAMBRIAN?)

The name Sierra de Perijá series has been used by Liddle (1943, p. 10) to designate a group of definitely pre-Devonian and probably pre-Cambrian rocks which are exposed in the headwaters of the Río Cachirí in the Sierra de Perijá of western Zulia (Fig. 3). In this paper the name is shortened to Perijá series.

Lithology.—The series is composed mainly of gray to tan, massive, bedded quartzites interbedded with greenish gray mica schists and gneissoid schists, all of which are cut by veins and dikes of white quartz. Intrusions of light-colored biotite granite are common with granodiorite and porphyritic quartz monzonite in subordinate amounts. A large mass of igneous rock, questionably identified as trachyte, is associated with the biotite granite in the Totumo area in the northern part of the District of Perijá, Zulia.

Thickness.—The thickness of the series is unknown but is at least several thousand feet.



TYPE LOCALITY MAP
MARACAIBO BASIN

FIG. 3

Stratigraphic relationship.—On the Río Cachirí the beds of the Perijá series underlie rocks of Devonian age, probably in fault contact. In any event there is pronounced angularity between the two. The intrusions do not extend into the Devonian rocks.

Distribution.—The Perijá series forms the core of the Sierra de Perijá. Igneous rocks of the types intruding the Perijá series occur also along the east flank of the range between Totumo and Inciarte, on Toas Island, and in Socuy well No. 1 in the District of Mara, Zulia.

Age and paleontology.—No fossils have been observed in the rocks of this series, and, aside from its pre-Devonian classification, no definite age assignment is possible. A pre-Cambrian age for some or all of its components is probable, however.

Correlation.—The Perijá series is believed to be correlative, within broad limits, with the Santo Domingo gneiss of the Mérida Andes, as described by Oppenheim, and the Iglesias series of Kündig (Figs. 4 and 5).

IGLESIAS SERIES (PRE-CAMBRIAN?)

The name Iglesias series has been applied by Kündig (1938, p. 22) to the older metamorphic series forming the core of the Mérida Andes. The type locality is the Cerro Las Iglesias, part of the Conejos massif, northwest of the city of Mérida.

Lithology.—According to Kündig, the Conejos massif is composed of biotitic orthogneiss, migmatitic gneiss with lit-par-lit aplitic injections, coarse-grained biotitic porphyroblastic augen gneiss, fine-grained gneiss containing garnet and biotite, and garnetiferous mica schist, while the Los Gatos massif consists of orthogneisses (dioritic gneisses, granitic gneisses), rare paragneisses and intruding amphibolite sills.

Thickness.—The thickness of the series is unknown but is at least several thousand feet.

Stratigraphic relationship.—The Mucuchachí series rests on the Iglesias series with probable unconformity.

Distribution.—The Iglesias series occurs in the Conejos massif on the northwest flank of the Mérida Andes and in the Los Gatos massif on the southeast flank. The Santo Domingo gneiss, a biotitic gneiss with injections of aplite, found by Oppenheim (1937, p. 31) in the upper Río Santo Domingo valley in northeastern Mérida also belongs in the Iglesias series.

Age and paleontology.—No fossils have ever been found in the Iglesias series, but its position beneath the Mucuchachí evidences an age older than Upper Cambrian. It appears to be entirely or partly pre-Cambrian.

Correlation.—The Iglesias series is roughly equivalent to the Perijá series on the west side of the Maracaibo basin and to the pre-Cambrian formations of the Guayana shield.

PALEOZOIC

CAMBRO-ORDOVICIAN

MUCUCHACHÍ SERIES (UPPER CAMBRIAN TO UPPER ORDOVICIAN)

The name Mucuchachí series was first used by Christ (1927, p. 397) to designate the metamorphosed sediments exposed near the town of Mucuchachí on

CORRELATION CHART
MARACAIBO BASIN

			BARCÓ CONCESSION (NOMENCLATURE OF NOTESTEIN ET AL)	TACHIRA	MERIDA	TRUJILLO	EAST ZULIA	WEST ZULIA
CENOZOIC	RECENT		TERRACE DEPOSITS	ALLUVIUM	ALLUVIUM	ALLUVIUM	ALLUVIUM	ALLUVIUM
	PLEISTOCENE					DIVIDIVE	EL MILAGRO	EL MILAGRO
	PLIOCENE		NECESIDAD					CERRO VIGIA
	MIOCENE	UPPER	GUAYABO	BETIJOQUE	BETIJOQUE	BETIJOQUE		
		MIDDLE		ISNOTU	ISNOTU	ISNOTU	LA PUERTA	LA VILLA
		LOWER	LEON	PALMAR	PALMAR	PALMAR	LAGUNILLAS	LOS RANCHOS
							LA ROSA	
	OLIGOCENE	UPPER						
		MIDDLE	CARBONERA	BEBEDERO	BEBEDERO		ICOTEA	EL FAUSTO
		LOWER				MENE GRANDE	AMBROSIO	
	EOCENE	UPPER	CARBONERA	LOBATERITA	LOBATERITA	PAUJI	LAS FLORES	LAS FLORES
				OMUQUENA	OMUQUENA		POTRERITOS	POTRERITOS
			MIRADOR	MIRADOR	MIRADOR	MISOA	MISOA	MISOA
		MIDDLE	LOS CUERVOS	ANGOSTURA	ANGOSTURA	TRUJILLO	TRUJILLO	MARCELINA
		LOWER	BARCO					
	PALEOCENE	UPPER				GUASARE	GUASARE	GUASARE
		LOWER						
MESOZOIC	CRETACEOUS	UPPER — DANIAN						
		MAESTRICHTIAN	CATATUMBO					
			MITO JUAN	MITO JUAN	MITO JUAN			MITO JUAN
		CAMPANIAN	COLON	COLON	COLON	COLON		COLON
		SANTONIAN						
		CONIACIAN	LA LUNA	LA LUNA	LA LUNA	LA LUNA		LA LUNA
		TURONIAN						
		MIDDLE — CENOMANIAN	COGOLLO	CAPACHO	CAPACHO	CAPACHO		CAPACHO
			AGUARDIENTE	AGUARDIENTE	AGUARDIENTE	AGUARDIENTE		AGUARDIENTE
		ALBIAN	MERCEDES	APON	APON	APON		APON
		APTIAN	TIBU					
		LOWER — BARREMIAN						RIO NEGRO
		HAUTERIVIAN						
		VALANGINIAN						
		BERRIASIAN						
	JURASSIC							
	TRIASSIC			LA QUINTA	LA QUINTA	LA QUINTA		LA QUINTA
PALEOZOIC	PERMIAN			PALMARITO	PALMARITO			PALMARITO
	PENNSYLVANIAN							
	MISSISSIPPIAN							
	DEVONIAN				MOMBOY	MOMBOY		CACHIRI
	SILURIAN							
	ORDOVICIAN				MUCUCHACHI	MUCUCHACHI		
	CAMBRIAN							
PROTEROZOIC					IGLESIAS & IGNEOUS			PERIJA & IGNEOUS
ARCHEOZOIC								

FIG. 4

the southeast flank of the Mérida Andes in the southern part of the State of Mérida.

Lithology.—In the type area, according to Oppenheim (1937, p. 33), the series includes schists and calcareous schists in the lower part, greenish gray and black slates in the middle, and schists and quartzites in the upper part. In the Maracaibo basin on the northwest flank of the Andes, near the village of Monte Carmelo in southwest Trujillo, the lower part of the series is composed of thinly to thickly bedded, gray to brown, hard, quartzitic sandstones and conglomerates interbedded with subordinate amounts of dark gray schist and impure limestone. Higher in the section silver-gray micaceous schists and black argillites predominate, and there are only rare beds of quartzitic sandstone. The series has here experienced two periods of granitic intrusion, the latter of which has penetrated younger overlying beds.

Thickness.—The thickness of the series in the Monte Carmelo area is unknown but probably exceeds 300 meters (984 feet).

Stratigraphic relationship.—The basal contact of the series has not been observed in the Maracaibo basin, but it is considered unconformable with the older igneous and metamorphic rocks which form the core of the range. Above, the series is unconformable with the Devonian Río Momboy beds.

Distribution.—The occurrence at Monte Carmelo is limited to a few miles along the northwest flank of the Mérida Andes from Monte Carmelo in southwest Trujillo to San Cristóbal in northern Mérida. Occurrences with similar lithology are present in southwestern Mérida near Mesa Bolívar, Zea and San Simón. Oppenheim (1937, p. 31) introduced the term Estanques gneiss for a heterogeneous assemblage of gneisses, quartzites, mica schists, phyllites, graphitic schists, and metamorphosed limestones in the valley of the Chama river near the town of Estanques in southwestern Mérida. This appears to be a phase of the Mucuchachí which has suffered more than the typical amount of metamorphism. In that respect, the Estanques gneiss resembles the Bellavista formation, which Kündig (1938, p. 24) separated from the Caparro-Bellavista group described by Christ (1927, p. 404). The Bellavista formation is composed of chloritic, sericitic, and graphitic schists and phyllites intruded by granite and granite porphyry. These rocks form the major portion of the Tovar, Avispa, and Capaz massifs on the northwestern flank of the Mérida Andes, the Sierra Nevada massif along the crest of the Andes, and the Colorado massif on the southeastern flank. The type locality of the Bellavista formation is in the Colorado massif on the trail from Santa Barbara to Mucuchachí. Kündig (1938, p. 28) placed the remainder of Christ's Caparro-Bellavista group in the Caparro group, which is fossiliferous and has never been metamorphosed. This group of sandstones and sandy shales is found along the Río Caparro on the same Santa Bárbara-Mucuchachí trail. Another possible occurrence of the Mucuchachí series is the Cerro Azul formation described by Mackenzie (1937, pp. 258–59). The type locality is the Cerro Azul uplift on the southeast slope of the Andes in the State of Barinas, where grayish

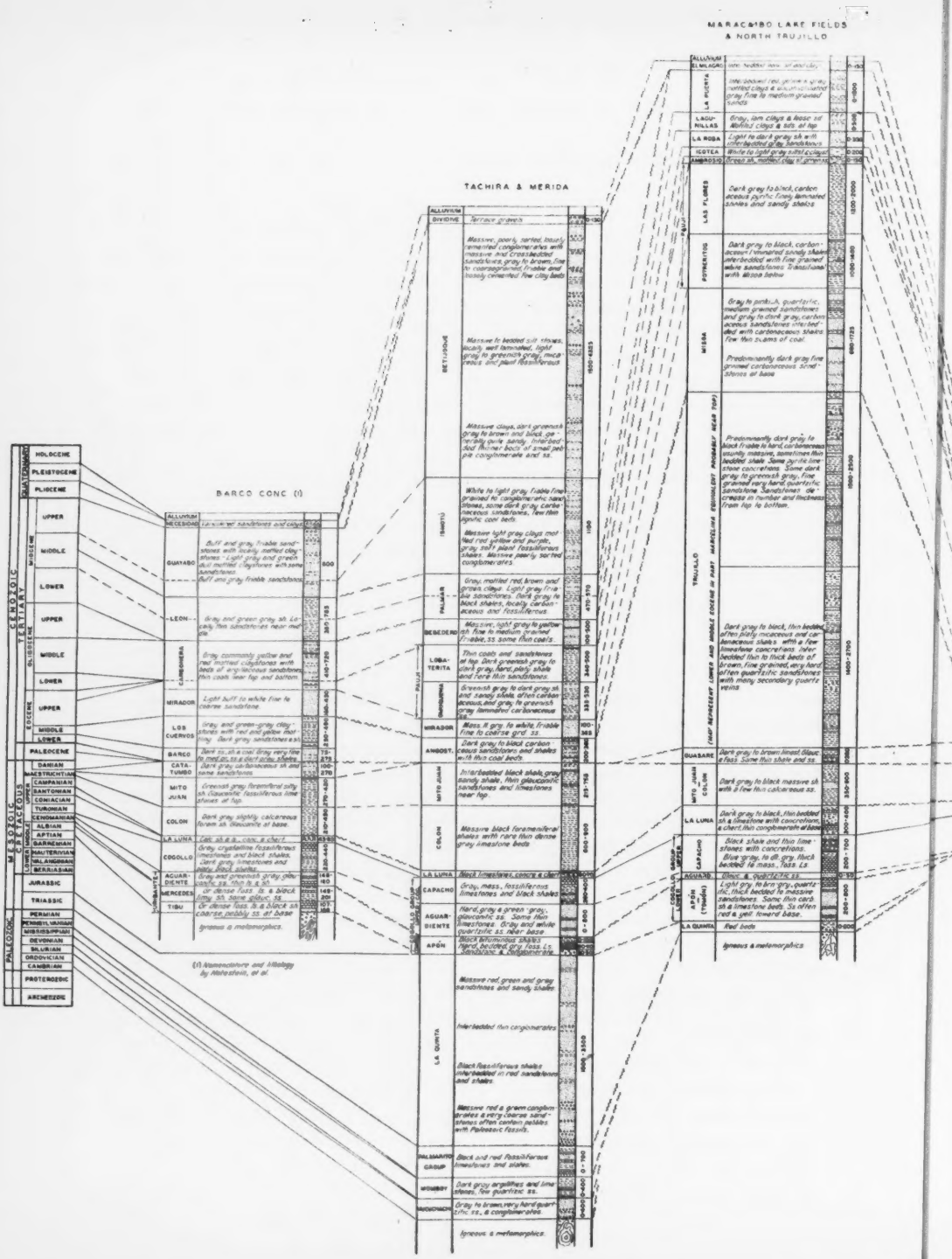
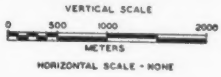

MARACAIBO LAKE FIELDS & NORTH TRUJILLO
TACHIRA & MERIDA
BARCO CONC (1)
CENOZOIC
MESOZOIC
PALEOZOIC
QUATERNARY
TERTIARY
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PROTEROZOIC
ARCHEOZOIC
HOLOCENE
PLEISTOCENE
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
DANIAN
MAESTRICHTIAN
CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
BERRIASIAN
ALLUVIUM
EL MILAGRO
LA PUERTA
LAGUNILLAS
LA ROSA
ICOTEA
AMBROSIO
LAS FLORES
PATRICIO
MISOA
TRUJILLO
GUASARE
MITO JUAN
COLON
LA LUNA
CAPACHO
AGUARDIENTE
APON
LA QUINTA
DIVISIVE
BETIJOQUE
ISNOTU
PALMAR
BOCONO
LOBATERITA
PANAMENA
MIRADOR
ANDOST.
MITO JUAN
COLON
LA LUNA
CAPACHO
AGUARDIENTE
APON
LA QUINTA
PALMARITO GROUP
MONEY
ESCUCHACHI
CRETACEOUS GROUP
JURASSIC GROUP
TRIASSIC
PALEOZOIC
CRETACEOUS
TERTIARY
CRETACEOUS
JURASSIC
TRIASSIC
PALEOZOIC
(1) Nomenclature and lithology by Hedberg, et al.

FIG. 5

GENERALIZED REPRESENTATIVE COLUMNAR SECTIONS

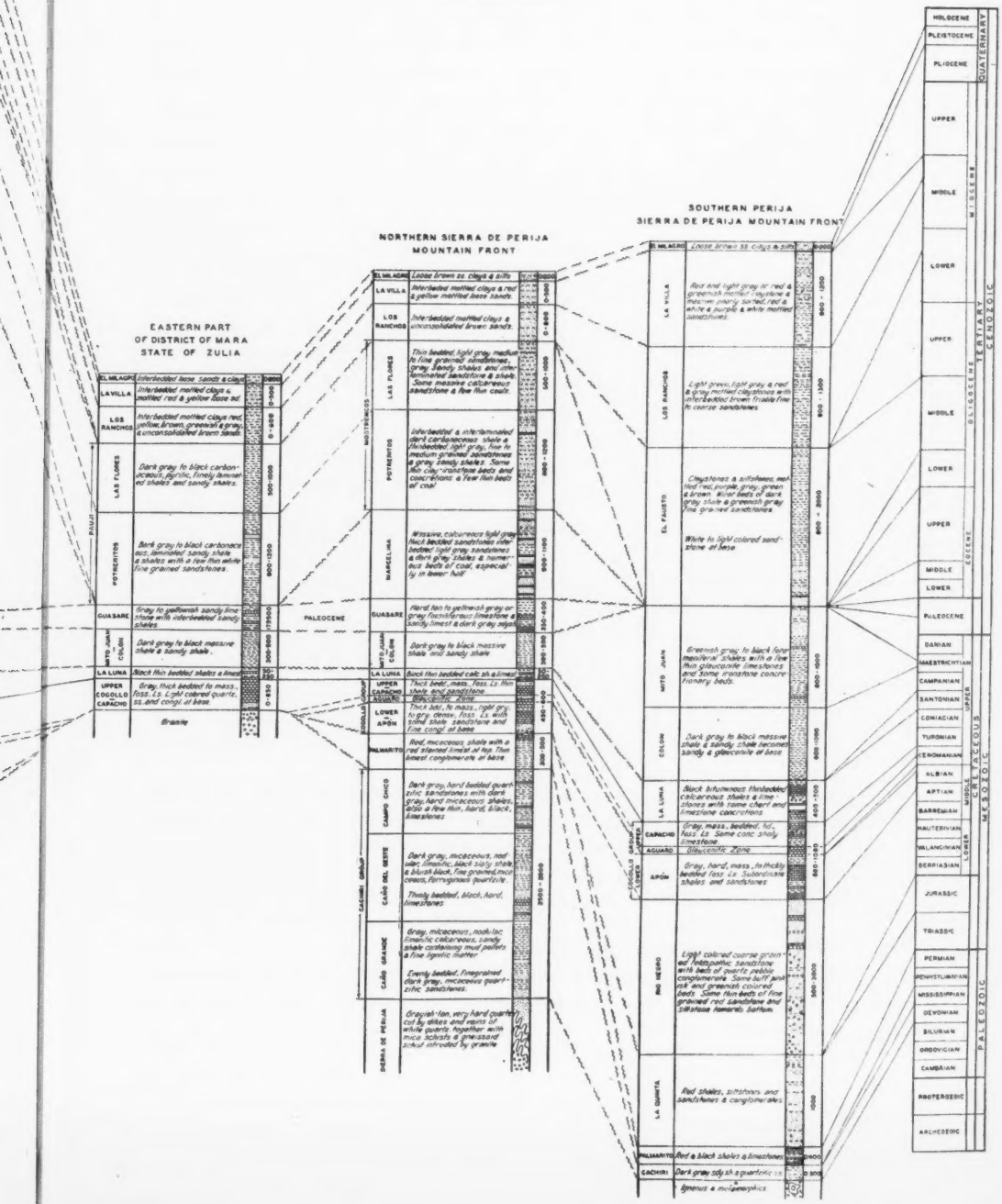
MARACAIBO BASIN



EASTERN PART OF DISTRICT OF MARA STATE OF ZULIA

NORTHERN SIERRA DE PERIJA MOUNTAIN FRONT

SOUTHERN PERIJA SIERRA DE PERIJA MOUNTAIN FRONT


EL MILAGRO
LA VILLA
LOS RANCHOS
LAS FLORES
FOTRERITOS
GUASARE
MITO JUAN
COLON
LA LUNA
UPPER COCOLLO
CAPACHO
LOWER COCOLLO
APON
MISOA
PALMARITO
CAMPO CHICO
CAÑO DEL NEGRO
CAÑO GRANDE
SIERRA DE PERIJA
MISOA-PALMARITO
LA QUINTA
CACHIRI
MOSTRENCOS
MARCELINA
PARAUL
CATATUMBO GROUP
PALEOCENE
CRETACEOUS
JURASSIC
PALEOZOIC
Interbedded loose sands & clays
Interbedded mottled clays & red & yellow loose sd
Interbedded mottled clays red, yellow, brown, greenish gray, & unconsolidated brown sands
Dark gray to black carbonaceous, pyritic, finely laminated shales and sandy shales
Dark gray to black carbonaceous, laminated sandy shale & shales with a few thin white fine grained sandstones
Gray to yellowish sandy lime stone with interbedded sandy shales
Dark gray to black massive shale & sandy shale
Black thin bedded shales & limest
Gray, thick bedded to mass., foss. Ls. Light colored quartz ss. and congl. at base
Granite
Loose brown ss. clays & silts
Interbedded mottled clays & red & yellow mottled loose sands
Interbedded mottled clays & unconsolidated brown sands
This bedded, light gray, medium to fine grained sandstones, gray, sandy shales and interlaminated sandstone & shale. Some massive calcareous sandstone & few thin coals
Interbedded & interlaminated dark carbonaceous shale & thinbedded light gray, fine to medium grained sandstones & gray, sandy shales. Some thin clay-ironstone beds and concretions & a few thin beds of coal
Wrinkly, calcareous light gray thick bedded sandstones interbedded light gray sandstones & dark gray shales & numerous beds of coal, especially in lower half
Hard tan to yellowish gray or gray fossiliferous limestone & sandy limest & dark gray shale
Dark gray to black massive shale and sandy shale
Black thin bedded calc sh & limes
Thick bed., mass., foss. Ls thin shale and sandstone
Glauconitic Zone
Thick bd., to mass., light gry. to gry. dense, foss. Ls. with thind shale sandstone and fine congl. at base
Red, micaceous shale with a red stained limest. at top. Thin lenses of conglomeratic at base
Dark gray, hard bedded quartzitic sandstones with dark gray hard micaceous shales, also a few thin, hard, black, limestones
Dark gray, micaceous, nodular, limonitic, black sandy shale, & bluish black, fine grained, micaceous, ferruginous quartzite.
Thinly bedded, black, hard, limestones
Gray, micaceous, nodular, limonitic calcareous, sandy shale containing mud pellets & fine lignitic matter.
Evenly bedded, finegrained dark gray, micaceous quartzitic sandstones.
Greyish-tan, very hard quartzite cut by dikes and veins of white quartz, together with mica schists & greissand schist intruded by granite
Loose brown ss. clays & silts
Red and light gray or red & greenish mottled claystone & massive, poorly sorted, red & white & purple & white mottled sandstones.
Light green, light gray & red & gray mottled claystones with interbedded brown friable fine to coarse sandstones
Claystones & siltstones, mottled red, purple, gray, green & brown. Minor beds of dark gray shale & greenish gray fine grained sandstones.
White to light colored sandstone at base
Brownish gray to black fossiliferous shales with a few thin glauconite limestones and some ironstone concretionary beds.
Dark gray to black massive shale & sandy shale becoming sandy & glauconitic at base
Black bituminous thinbedded calcareous shales & limestones with some chert and limestone concretions
Gray, mass., bedded, hd., foss. Ls. Some conc shaly limestone
Glauconitic Zone
Gray, hard, mass., in thickly bedded foss. Ls. Subordinate shales and sandstones
Light colored coarse grained feldspathic sandstone with beds of quartz pebble conglomerate. Some buff and pink and greenish colored beds. Some thin beds of fine grained red sandstone and siltstone. Remarks, Barban.
Red shales, siltstones and sandstones & conglomerates
Red & black shales & limestones
Dark gray sdy sh & quartzitic ss
Igneous & metamorphics
EL MILAGRO
LA VILLA
LOS RANCHOS
EL FAUSTO
MITO JUAN
COLON
LA LUNA
CAPACHO
AGUARO
APON
RIO NEGRO
LA QUINTA
PALMARITO
CACHIRI
MIOCENE
PLEISTOCENE
PLIOCENE
UPPER
MIDDLE
LOWER
OLIGOCENE
EOCENE
PALEOCENE
DANIAN
MAESTRICHTIAN
CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
BERRIASIAN
JURASSIC
TRIASSIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PROTEROZOIC
ARCHEOZOIC
QUATERNARY
TERTIARY
CRETACEOUS
MESOZOIC
PALEOZOIC
CENOZOIC

green, highly compacted, siliceous shale is exposed in a veined, sheared, and faulted outcrop 1,600 to 1,800 meters (5,250 to 5,900 feet) thick.

Age and paleontology.—No fossils have been found in this series within the Maracaibo basin, but it must be older than the overlying Devonian Río Momboy formation. On the opposite slope of the Mérida Andes lies Kündig's Caparro group in which Terry (Schuchert, 1935, p. 694) found the graptolite *Dicranograptus caparroensis* n. sp., and the trilobite *Cryptolithus terryi* n. sp. This faunule is Trenton in age and has therefore been called upper Middle Ordovician by American paleontologists, but, by reference to the European time scale, it must be assigned to the Caradocian stage or lower Upper Ordovician. A. A. Olsson (verbal communication) considers the Caparro as the unmetamorphosed equivalent of the upper part of the Mucuchachí series. Unfortunately, it has been difficult in places to differentiate between the Mucuchachí and overlying younger metamorphics. Thus Kehrer, according to Oppenheim (1937, p. 34), "showed us a neat impression of a brachiopod, possibly a *Spirifer*, found in the slates of the Mucuchachí series in the Libertad zone." This probably was collected from the Devonian Río Momboy formation. Again, Kehrer (1938, p. 53) mentions ammonites and *Halobia?* sp. from the Mucuchachí series near the town of Mucuchachí. These may have come from the Upper Triassic beds of the La Quinta formation, which rests unconformably on the Mucuchachí series in the type area of the Mucuchachí.

Correlation.—Olsson in unpublished reports correlates the Mucuchachí series with Hettner's Quetame series in Colombia. Trümpy (1943, pp. 1287–1290) reports that fossils of Upper Cambrian and Lower Ordovician age have been found in the Güejar series, a less metamorphosed equivalent of the Quetame. Then, if the Upper Ordovician fossils of the Caparro are considered to have occurred in the equivalent of the upper Mucuchachí, the age of both the Quetame and the Mucuchachí series must extend from Upper Cambrian to Upper Ordovician.

DEVONIAN

CACHIRÍ GROUP (DEVONIAN)

The term Río Cachirí series was introduced by Liddle (1928, pp. 97–99) to designate the sediments lying between the redbeds and the metamorphics on the upper Cachirí River in the District of Maracaibo, State of Zulia. To conform with standard usage the name has been changed to Cachirí group. The Devonian Cachirí group should not be confused with Garner's (1926, p. 679) Cachirí limestone, an obsolete name once used for the faulted incomplete section of the Middle Cretaceous Cogollo group on the lower Río Cachirí.

Lithology.—Where exposed at the type locality, the Cachirí group is composed largely of gray to dark gray, micaceous, limonitic, and calcareous shales which contain fine particles of lignitic material. Present throughout are intervals of fine-grained, gray to dark gray, micaceous, quartzitic sandstone. Liddle (1943, pp. 14–21) has suggested a three-fold division of the group on the basis of

lithology and believes that the entire Devonian period may be represented in the section exposed. From bottom to top his divisions are the Caño Grande formation, Cano del Oeste formation, and Campo Chico formation. These are gradational one with the other.

Thickness.—At the type section, the group has a thickness of 2,600 meters (8,530 feet). This is believed to be the maximum for the Devonian of Venezuela.

Stratigraphic relationship.—At its base the Cachirí is discordant and probably in fault contact with the metamorphic and igneous rocks of the Perijá series, while above, it is unconformable with the Permo-Pennsylvanian Palmarito series.

Distribution.—Sediments of the Cachirí group are found along the Sierra de Perijá front from the Río Cachirí southward to the Ríos Tinacoa and Macoita, while sediments which are considered the same in age are present along the northwestern flank of the Mérida Andes on the opposite side of the basin in the states of Táchira, Mérida, and Trujillo.

Age and paleontology.—The fossils collected from the Caño Grande formation have been identified and published in two papers, the first by Weisbord (1926), the second by Liddle, Harris, and Wells (1943). The rich fauna permits its tentative identification as Onondaga in age and its correlation with the Floresta fauna of Colombia, described by Caster (1939). The Onondaga has generally been regarded by American paleontologists as lowermost Middle Devonian, but reference to the European time scale indicates an upper Coblenzian or uppermost Lower Devonian age.

A few of the fossils published by Weisbord were apparently collected from a fossiliferous bed in the lower part of the Caño del Oeste formation in the Caño del Oeste. Of these, *Brachyspirifer audaculus* (Conrad) var. *zuliana* (Weisbord), is the outstanding species both in size and numbers. It is evidence of Marcellus or Hamilton (Middle Devonian) age.

The Campo Chico formation is unfossiliferous and has been tentatively placed in the Upper Devonian by Liddle due to its stratigraphic position and transitional contact with the underlying Caño del Oeste formation.

Correlation.—Only on the Río Cachirí have the fossil-bearing beds of the Lower and Middle Devonian been observed in place, although fossiliferous float from this formation has been reported from the Río Guasare and Río Socuy, near the north end of the Sierra de Perijá. Formations which have been referred to by some geologists as the Tinacoa and Macoita, and which crop out along rivers bearing the same names on the south of the Cachirí type section, are believed to be equivalent to the upper unfossiliferous portion of the Cachirí group. Liddle (1943, pp. 19, 21) suggests a correlation of the Caño del Oeste and Campo Chico formations with the Tinacoa and Macoita formations, respectively. South of Valera in the State of Trujillo, on the eastern side of the basin, Liddle (1928, pp. 99–101) named and described the Río Momboy formation from outcrops in the Río Momboy valley. The Devonian age of at least part of these beds is based on his report of the presence of the brachiopod "*Spirifer arenosus*" in

float found in the Río Momboy. Later work has indicated that he included within his limits some beds which should be assigned to the older Mucuchachí series. The Río Momboy sediments have suffered considerably more metamorphism than their equivalents on the Río Cachirí and are composed mainly of thinly bedded, dark gray to bluish gray argillites, and argillaceous limestones with green, bedded, quartzitic sandstones here and there.

PERMO-CARBONIFEROUS

PALMARITO SERIES (PERMO-PENNSYLVANIAN)

The name Palmarito was introduced by Christ (1927, p. 402) to describe a series of shales and limestones exposed near Palmarito ranch in southern Mérida. Since that time sediments of this series have been recognized and described from a number of localities in the Sierra de Perijá and Mérida Andes. Though changes in lithology and thickness are common, the fossil evidence generally present indicates a late Carboniferous to early Permian age.

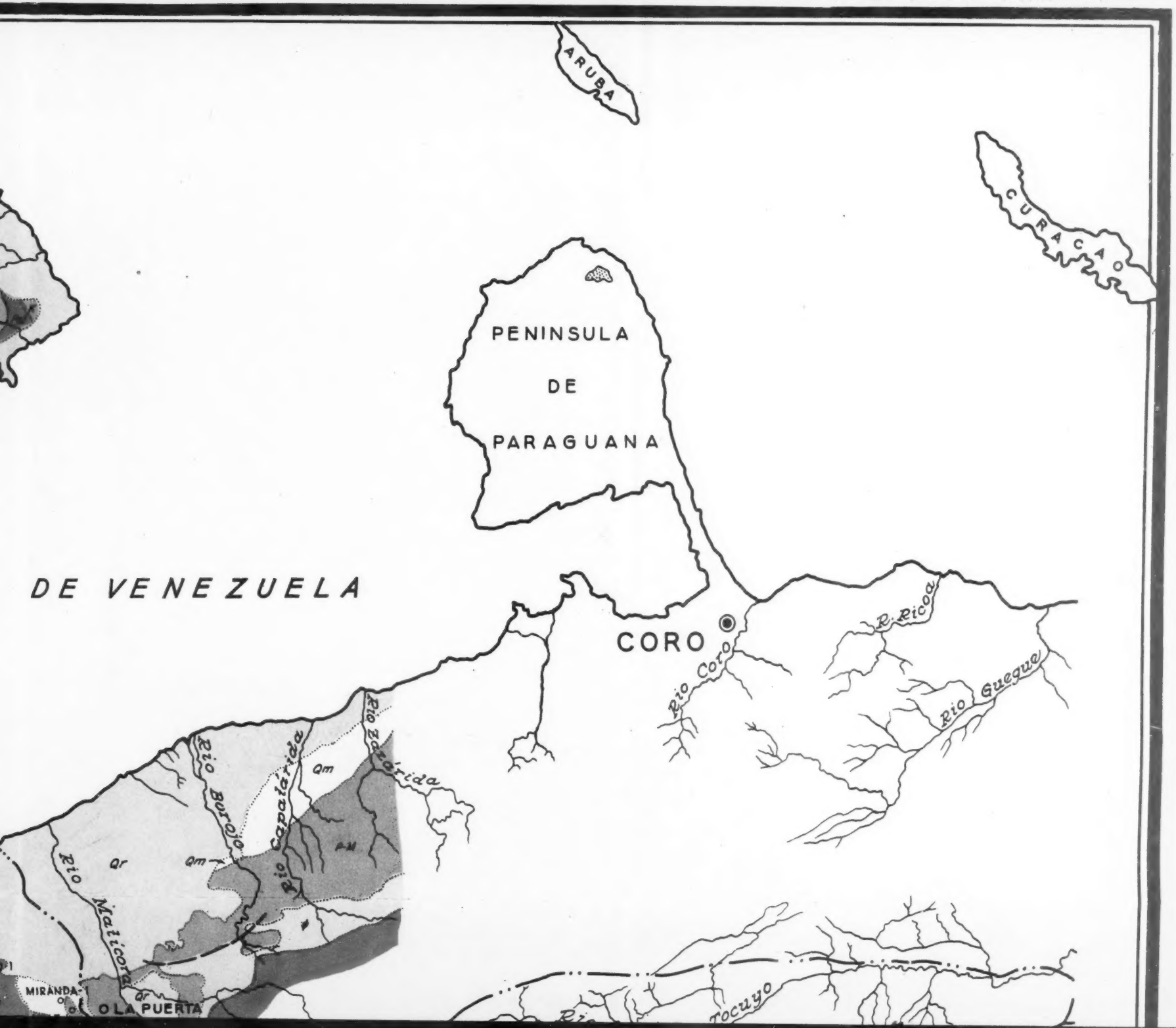
Lithology.—At the type locality the Palmarito is composed mainly of soft, blue-gray shale and massive, dark gray to blue-black, hard limestones. Near the "Paramo" of Zumbador in northeastern Táchira a greater thickness of the same series is present, and here the beds of the type locality grade downward into dark gray slates and argillites with subordinate amounts of green and red slate. Across the basin on the Río Cachirí in the Sierra de Perijá, the series is composed largely of red, bedded, micaceous shale and sandy shale with a suggestion of limestone conglomerate at its base, and near the top of the Caño del Norte section is a massive gray limestone bed about 5 feet thick, which contains a profusion of large crinoid stems. Small dikes and sills of rhyolite, andesite, and basalt intrude the Palmarito in most of western Zulia.

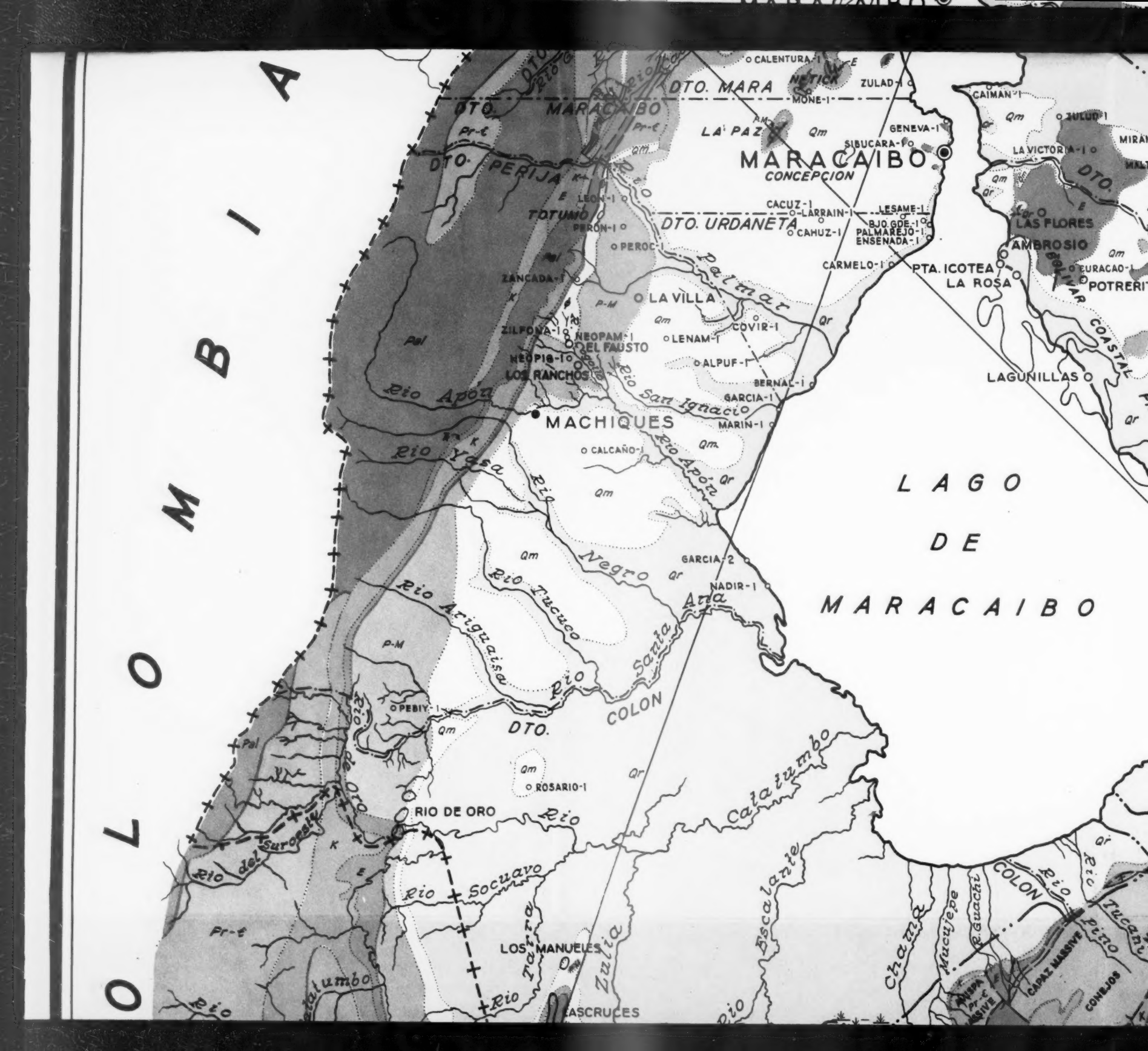
Thickness.—No reliable measurements of thickness are available for the Palmarito series in the type area of the Mérida Andes, although casual observation indicates at least 1,800 meters (5,906 feet). This is believed to be the area of greatest thickness, and thinning toward both north and south. On the Río Cachirí, where the beds are relatively undisturbed, the Palmarito has a measured thickness of 365 meters (1,198 feet).

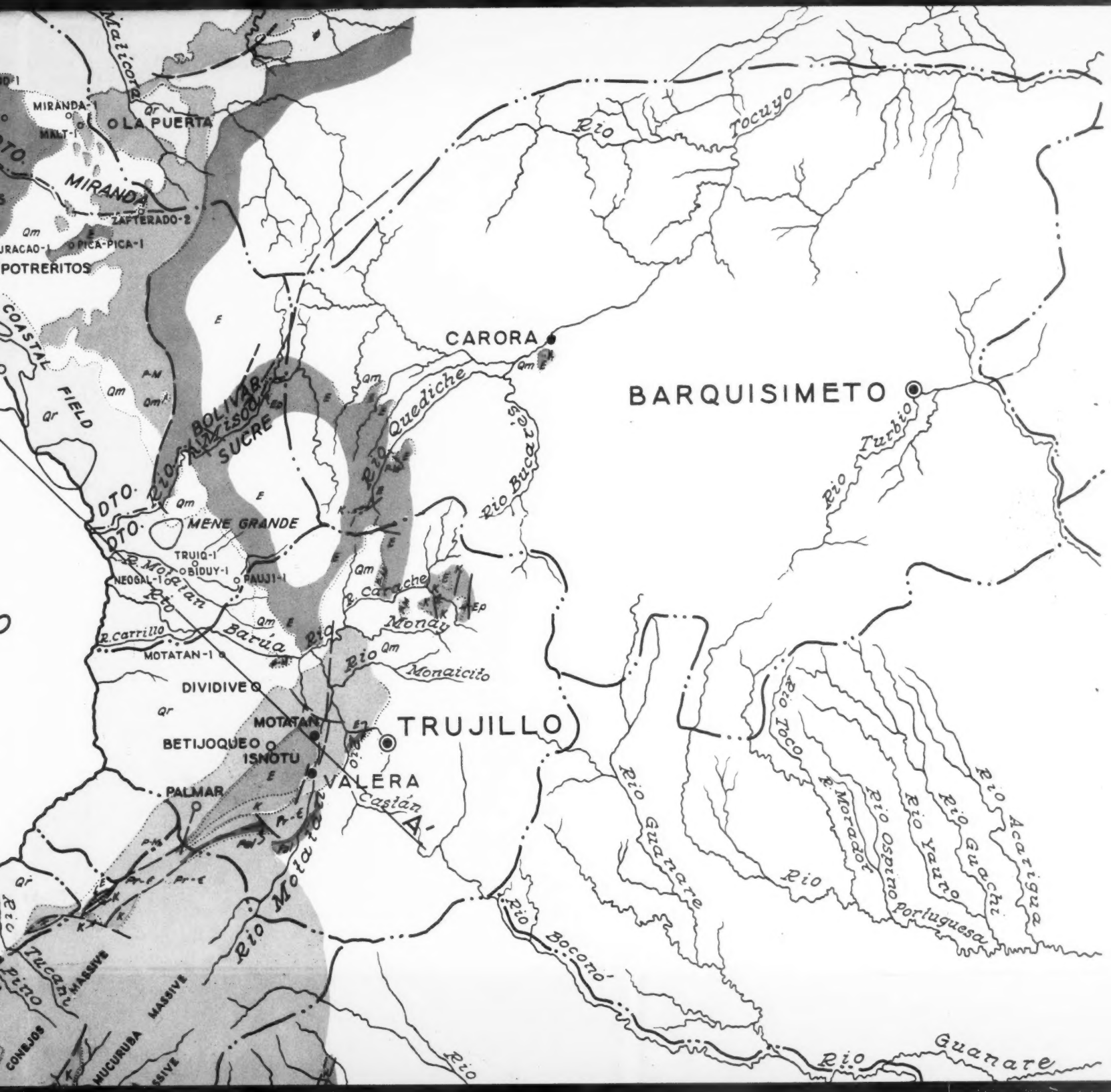
Stratigraphic relationship.—The Palmarito series occupies an isolated position in the stratigraphic sequence with long periods of erosion preceding and succeeding its deposition. At its base it may be in contact with beds ranging from Devonian to pre-Cambrian and above with beds ranging from the Triassic through the Tertiary. Angularity is generally present with overlying beds and the same relation undoubtedly exists with older formations, although the basal contact is generally too obscure to permit accurate observation.

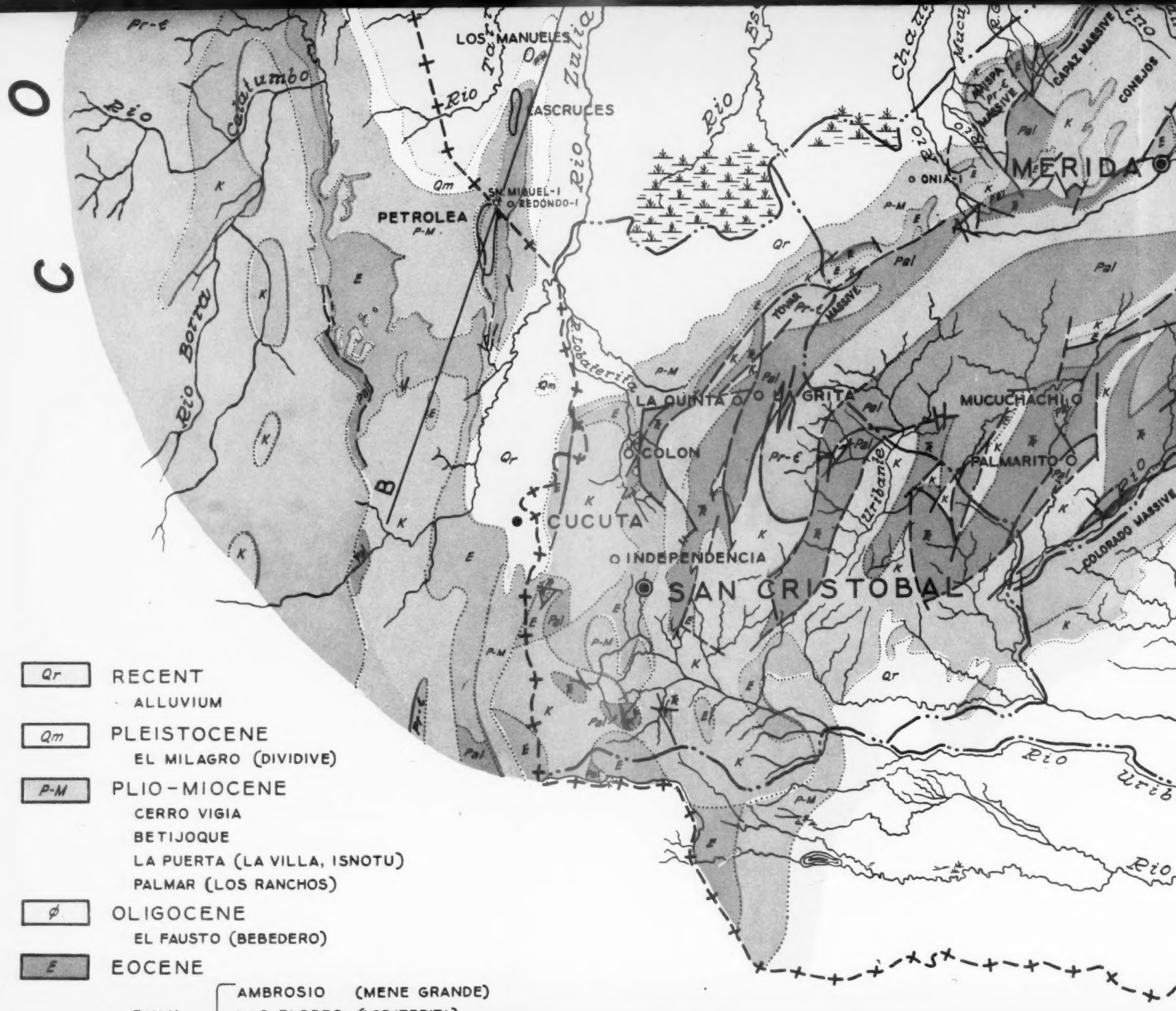
Distribution.—The Palmarito series is distributed extensively throughout the Mérida Andes and along the eastern slopes of the Sierra de Perijá. It is reported to increase in thickness southward in this range. The redbeds of Toas Island probably belong to this series.

PENINSULA DE LA GOAJIRA
GOLFO DE
Rio Calancala
Rio Ranchería
A
A'
B
B'
DTO. PAEZ
Rio Guasare
Rio Socuy
Rio Limón
DTO. MARACAIBO
DTO. MARA
LA PAZ
TETONES
CALENTURA-I
MONE-I
ZULAD-I
I. DE TOAS
GENEVA-I
SIBUCARA-Po
CAIMAN-I
LA VICTORIA-I
EPENG-I
AMANA-Io
MAREN-I
AMBOY-I
VEMOR-I
Pr-€
Qm
qr
EP
P-M
K


ARUBA
CURACAO
PENINSULA
DE
PARAGUANA
DE VENEZUELA
CORO
R. Rica
Rio Coro
Rio Guegue
Rio Capatárida
Rio Zazárida
Rio Borojo
Rio Maticora
Qm
Qr
Pl
MIRANDA
OLA PUERTA
Tocuyo


COLOMBIA
DTO. MARACAIBO
DTO. PERIJA
DTO. MARA
DTO. URDANETA
DTO. COLON
MARACAIBO
CONCEPCION
LA PAZ
TOTUMO
LA VILLA
MACHIQUES
LOS RANCHOS
EL FAUSTO
LAGO DE MARACAIBO
LAGUNILLAS
LAS FLORES
AMBROSIO
PTA. ICOTEA
LA ROSA
RIO DE ORO
LOS MANUELES
CALENTURA-1
ZULADI-1
CAIMAN-1
MONE-1
GENEVA-1
SIBUCARA-1
LA VICTORIA-1
LEON-1
CACUZ-1
LARRAIN-1
LESAME-1
BJO. GDE.-1
PALMAREJO-1
ENSENADA-1
PERON-1
PEROC-1
CAHUZ-1
CARMELO-1
ZANCADA-1
ZILFONA-1
NEOPAM-1
NEOPIS-1
COVIR-1
LENAM-1
ALPUF-1
BERNAL-1
GARCIA-1
MARIN-1
CALCAÑO-1
GARCIA-2
NADIR-1
PEBIY-1
ROSARIO-1
CURACAO-1
POTRERITO
Río Apón
Río Yasa
Río San Ignacio
Río Negro
Río Tucuco
Río Arigua
Río Palmar
Río Socuavo
Río Catatumbo
Río Escalante
Río Chama
Río Mucujepe
Río Tucani
COASTAL
Pr-ε
Pal
K
E
Qm
Qr
P-M


Maticora
MIRANDA-1
MNLT-1
LA PUERTA
MIRANDA
ZAPTERADO-2
PICA-PICA-1
POTRERITOS
COASTAL
FIELD
BOLIVAR
LIMISO
SUCRE
DTO.
MENE GRANDE
TRUIQ-1
BIDUY-1
PAUJI-1
NEOGAL-1
R. Motatan
Rio Motatan
R. carrillo
MOTATAN-1
Rio Barúa
DIVIDIVE
MOTATAN
BETIJOQUE
ISNOTU
PALMAR
Rio Motatan
Rio Tucani
MASSIVE
CONEJOS
MUCURUBA
Rio Pino
CARORA
Rio Quediche
Rio Buco
Rio Caracha
Rio Monay
Rio Monaicito
TRUJILLO
VALERA
Rio Castán
Rio Tocuyo
BARQUISIMETO
Rio Turbio
Rio Guanare
Rio Morador
Rio Ospino
Rio Yaro
Rio Guachi
Rio Acarigua
Rio Boconó
Rio Guanare



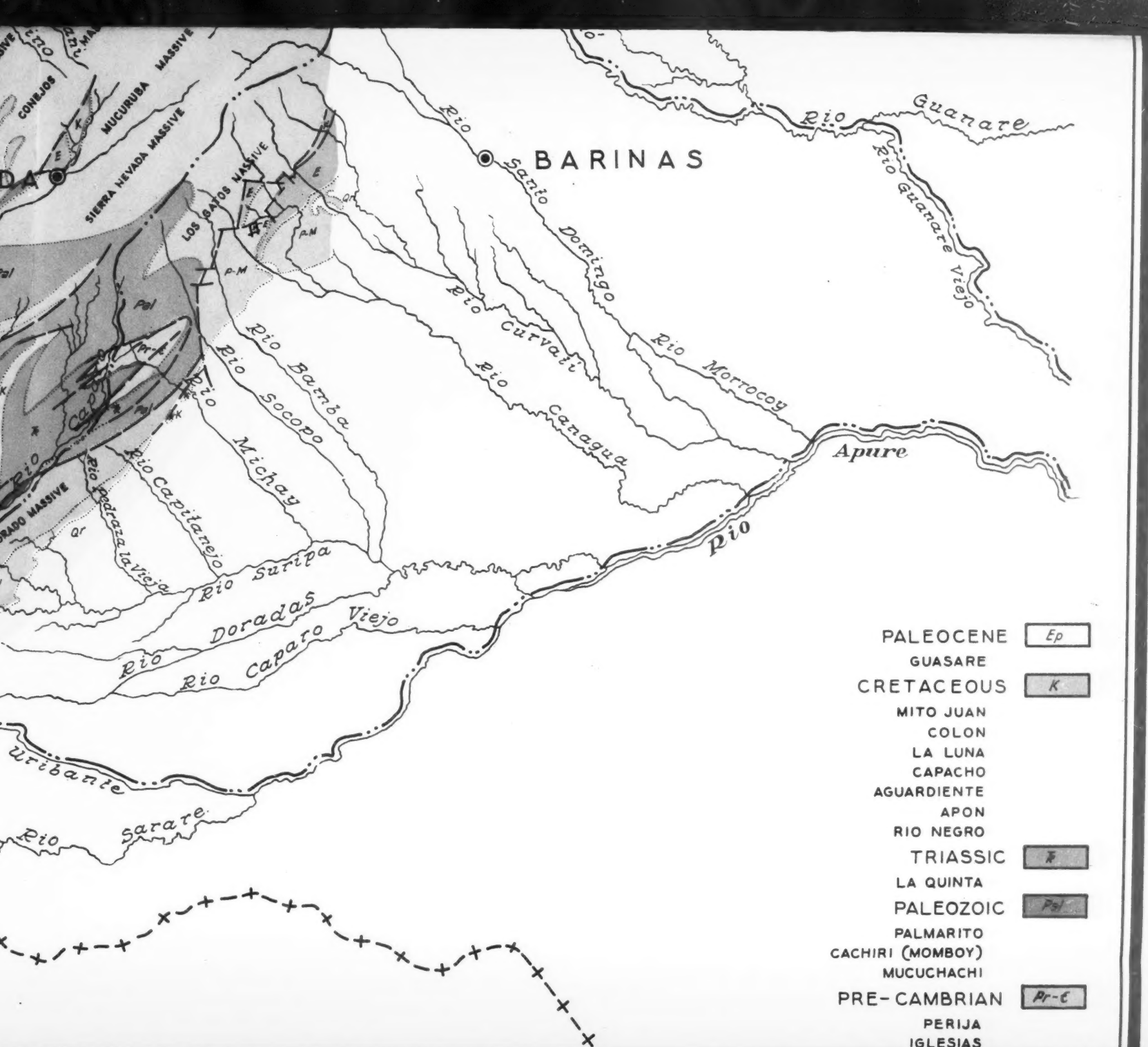
Qr RECENT
ALLUVIUM

Qm PLEISTOCENE
EL MILAGRO (DIVIDIVE)

P-M PLIO-MIOCENE
CERRO VIGIA
BETIJOQUE
LA PUERTA (LA VILLA, ISNOTU)
PALMAR (LOS RANCHOS)

ϕ OLIGOCENE
EL FAUSTO (BEBEDERO)

E EOCENE
PAUJI { AMBROSIO (MENE GRANDE)
LAS FLORES (LOBATERITA)
POTRERITOS (OMUQUENA)
MISOA (MIRADOR)
TRUJILLO ANGOSTURA, (MARCELINA)


BARINAS
Rio Santo Domingo
Rio Guanare
Rio Guanare Viejo
Rio Morrocoy
Rio Curvati
Rio Canagua
Rio Bamba
Rio Socopo
Rio Michay
Rio Capitanejo
Rio Pedraza la Vieja
Rio Suripa
Rio Doradas
Rio Caparo Viejo
Apure
Rio
Uribante
Rio Sarare
SIERRA NEVADA MASSIVE
MUCURUBA MASSIVE
LOS GATOS MASSIVE
CONEJOS
PALEOCENE Ep
GUASARE
CRETACEOUS K
MITO JUAN
COLON
LA LUNA
CAPACHO
AGUARDIENTE
APON
RIO NEGRO
TRIASSIC Tr
LA QUINTA
PALEOZOIC Pal
PALMARITO
CACHIRI (MOMBOY)
MUCUCHACHI
PRE-CAMBRIAN Pr-C
PERIJA
IGLESIAS

CERRO VIGIA
BETIJOQUE
LA PUERTA (LA VILLA, ISNOTU)
PALMAR (LOS RANCHOS)

Ø OLIGOCENE

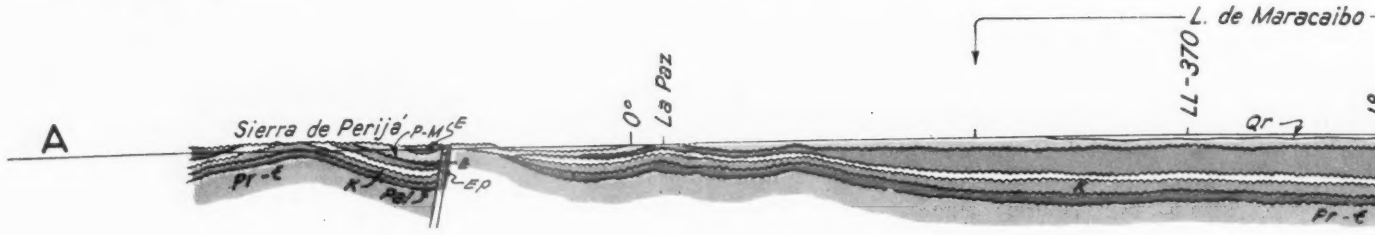
EL FAUSTO (BEBEDERO)

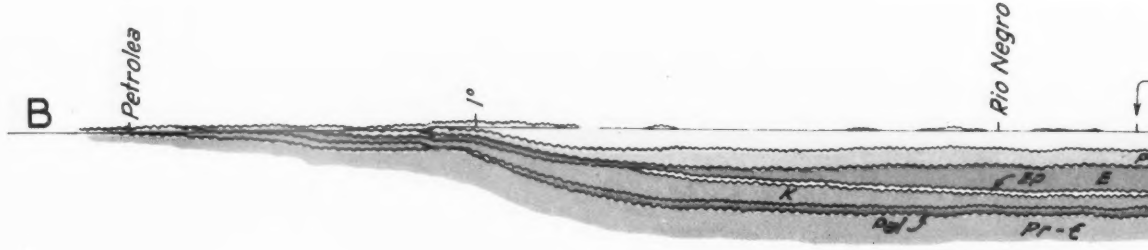
E EOCENE

PAUJI { AMBROSIO (MENE GRANDE); LAS FLORES (LOBATERITA); POTRERITOS (OMUQUENA)

MISOA (MIRADOR)

TRUJILLO ANGOSTURA, (MARCELINA)

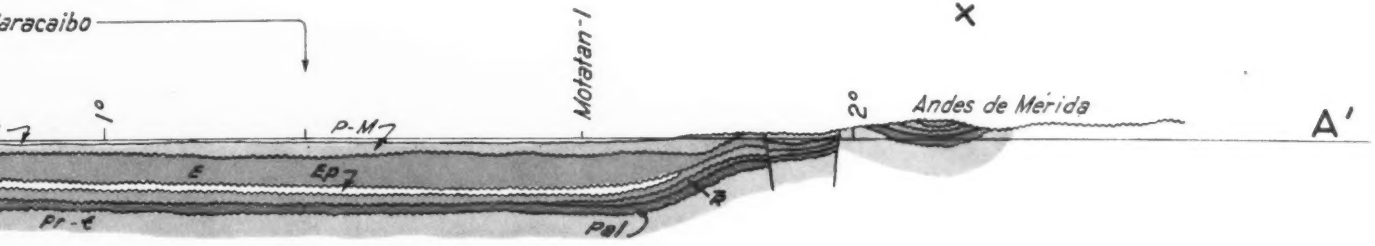


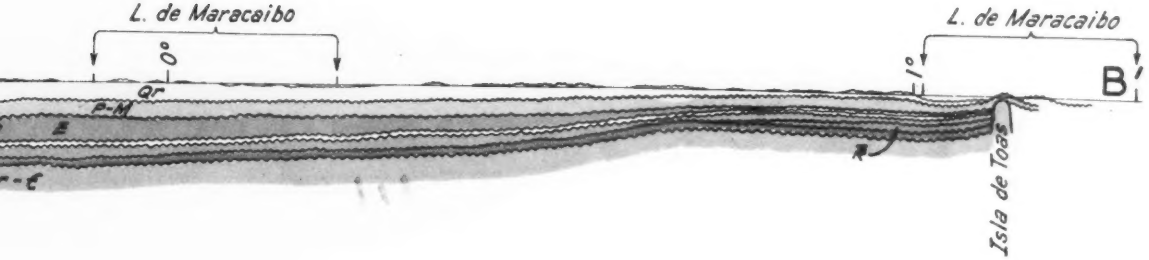


GEOLOGIC MAP
AND
CROSS - SECTIONS
MARACAIBO BASIN - VENEZUELA

Rio Sarare

AGUARDIENTE
APON
RIO NEGRO
TRIASSIC
LA QUINTA
PALEOZOIC
PALMARITO
CACHIRI (MOMBOY)
MUCUCHACHI
PRE-CAMBRIAN
PERIJA
IGLESIAS





SCALE 1: 1,000,000

0 10 20 30 40 50 60 70 80 90 100
KILOMETERS

0 10 20 30 40 50 60 70 80
MILES

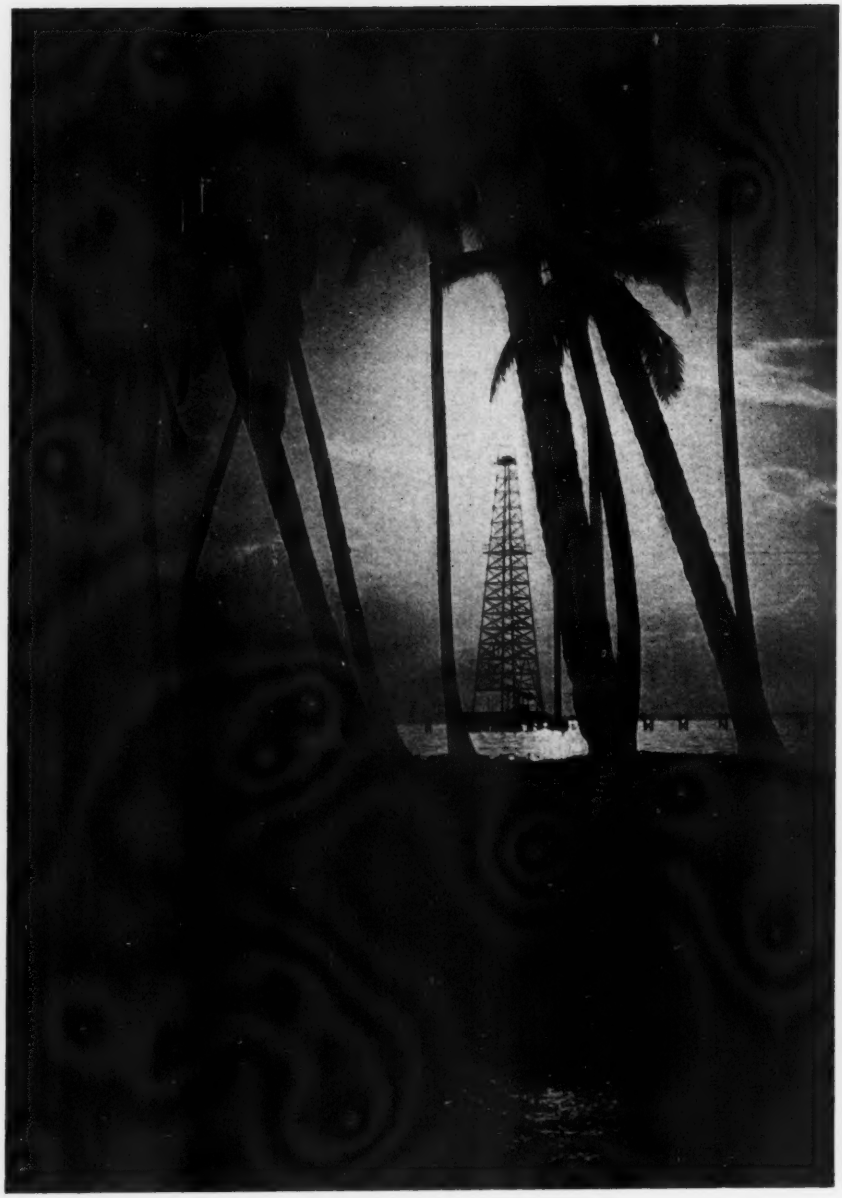


PLATE 2
Lake Maracaibo, Venezuela

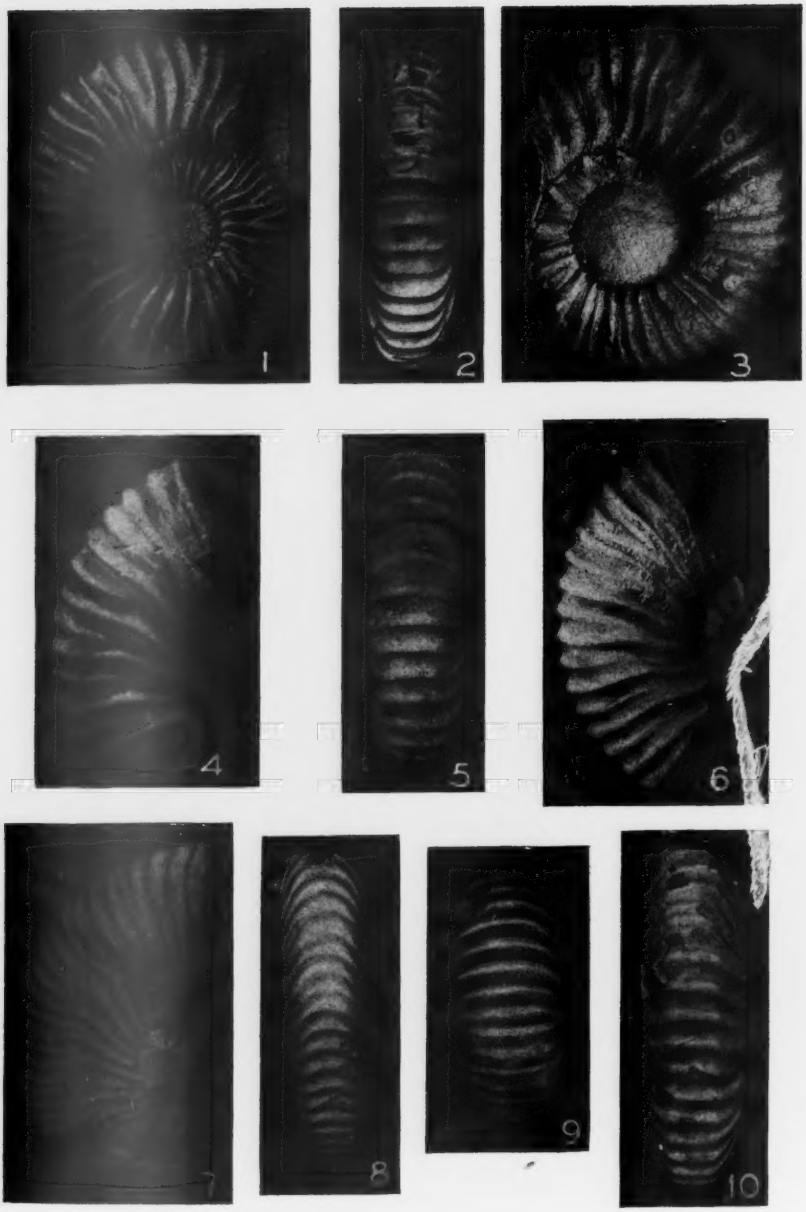
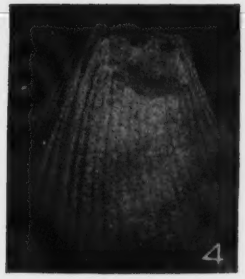
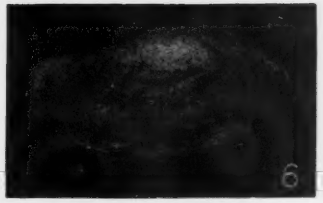


PLATE 3

Upper Aptian ammonites from Apón formation, Cogollo group.

FIG. 1.—*Deshayesites columbianus* Reidel. LOC.: Río La Ge. COLL., R. A. Liddle. P.R.I. No. 20,181.
FIG. 2.—Venter of same specimen as Fig. 1.
FIG. 3.—*Cheloniceras* cf. *cornueli* d'Orbigny. LOC.: Curiti, Colombia. COLL., A. A. Olsson. P.R.I. No. 20,182.
FIG. 4.—*Parahoplites* cf. *inconstans* Reidel. LOC.: Río Negro. P.R.I. No. 20,183; Creole Ser. No. 13,168.
FIG. 5.—Venter of same specimen as Fig. 4.
FIG. 6.—*Deshayesites?* sp. LOC.: Río Cogollo. Float boulder. Creole Ser. No. 13,157; P.R.I. No. 20,179.
FIG. 7.—*Deshayesites* cf. *stutzeri* Reidel. LOC.: Río Negro. P.R.I. No. 20,180; Creole Ser. No. 13,168.
FIG. 8.—Venter of same specimen as Fig. 7.
FIG. 9.—*Cheloniceras?* sp. LOC.: Río Negro. P.R.I. No. 20,184; Creole Ser. No. 13,168.
FIG. 10.—Venter of same specimen as Fig. 6.





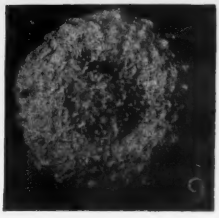


PLATE 4

Cretaceous fossils from Cogollo group.

FIG. 1.—*Polorthus?* sp. LOC.: Río Cogollo, E. bank about 550 meters downstream from junction with Río Seco. Apón formation. Creole Ser. No. 9,544; P.R.I. 20,141.

FIG. 2.—*Ostrea scyphax* H. Coquand. LOC.: S. bank Río Apón, 100 meters upstream from La Luna contact. Capacho formation. Creole Ser. No. 9,603; P.R.I. 20,149.

FIGS. 3, 4.—*Veithea aequicostata* d'Orbigny. LOC.: S. bank Río Apón, 100 meters upstream from La Luna contact. Capacho formation. Creole Ser. No. 9,603; P.R.I. 20,150.

FIGS. 5, 6.—*Panopea plicata* Sowerby. LOC.: Río Negro. Apón formation. P.R.I. 20,185.

FIG. 7.—*Holectypus* sp. LOC.: W. bank Río Cogollo 925 meters downstream from junction with Río Seco. Apón formation. Creole Ser. No. 9,548; P.R.I. 20,143.

FIG. 8.—*Hardouinia?* sp. LOC.: W. bank Río Cogollo 925 meters downstream from junction with Río Seco. Apón formation. Creole Ser. No. 9,548; P.R.I. 20,144.

FIG. 9.—*Phymosoma* cf. *texanum* (Roemer). LOC.: W. bank Río Cogollo 925 meters downstream from junction with Río Seco. Apón formation. Creole Ser. No. 9,548; P.R.I. 20,142.

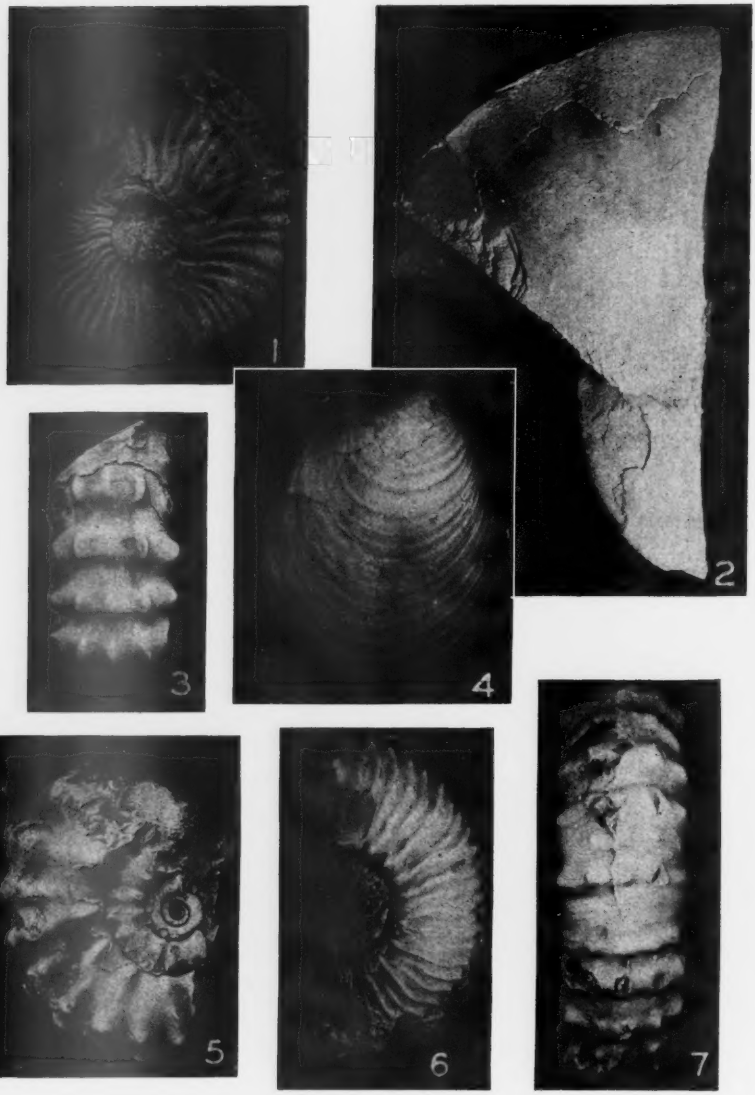


PLATE 5

Cretaceous fossils from La Luna formation.

FIG. 1.—*Discohoplites?* cf. *D. subfalcatus* (Semenow). Loc.: On Quebrada La Luna 425 meters downstream from Cogollo contact. Creole Ser. No. 9,566; P.R.I. 20,147.

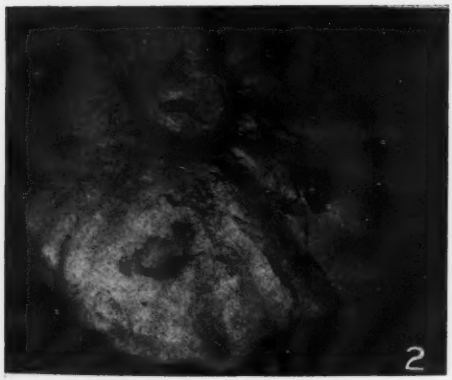
FIG. 2.—*Coilopoceras* sp. Loc.: Float specimen from Quebrada La Luna. Creole Ser. No. 13,134; P.R.I. 20,164.

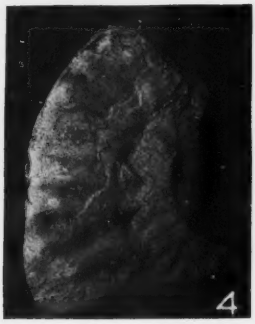
FIGS. 3, 5.—*Protacanthoceras?* cf. *Lyelliceras scheibei* Reidel. Loc.: Quebrada La Luna. COLL., R. A. Liddle. P.R.I. 20,300.

FIG. 4.—*Inoceramus labiatus* Schlotheim. Loc.: First concretionary beds exposed above Cogollo formation, Quebrada La Luna. Creole Ser. No. 13,130; P.R.I. 20,162.

FIG. 6.—*Eucalycoceras* sp. Loc.: Quebrada La Luna, Collector, A. A. Olsson. P.R.I. 20,301.

FIG. 7.—*Eucalycoceras* sp. Loc.: First concretionary beds exposed above Cogollo formation, Quebrada La Luna. Creole Ser. No. 13,130; P.R.I. 20,161.





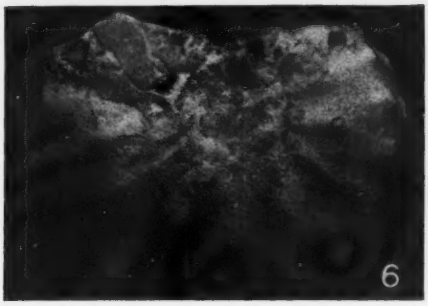


PLATE 6

Cretaceous fossils from La Luna formation.

FIG. 1.—*Prionotropis?* sp. LOC.: In first concretionary layer above Cogollo contact, Quebrada La Luna, Dist. of Perijá Zulia. Creole Ser. No. 9,564; P.R.I. 20,146.

FIG. 2.—*Barroisiceras* (*Harleites?*) *subtuberculata* Gerhardt. LOC.: Quebrada La Luna. COLL., R. A. Liddle. P.R.I. 20,188.

FIG. 3.—*Didymotis variabilis* Gerhardt. LOC.: Quebrada La Luna. COLL., R. A. Liddle. P.R.I. 20,187.

FIGS. 4, 5.—*Peroniceras* cf. *moureti* de Grossouvre. LOC.: In limestone concretions 190 meters upstream from La Luna-La Sierra contact, Quebrada La Luna. Creole Ser. No. 13,139; P.R.I. 20,168.

FIG. 6.—*Barroisiceras* (*Alstadenites*) cf. *sevierense* Reeside. LOC.: In limestone concretions 190 meters upstream from La Luna-La Sierra contact, Quebrada La Luna. Creole Ser. No. 13,139; P.R.I. 20,166.

FIG. 7.—*Barroisiceras* cf. *brancoi mite* Solger. LOC.: Float from La Luna formation where cart road crosses Quebrada La Luna. Creole Ser. No. 13,136½; P.R.I. 20,169.

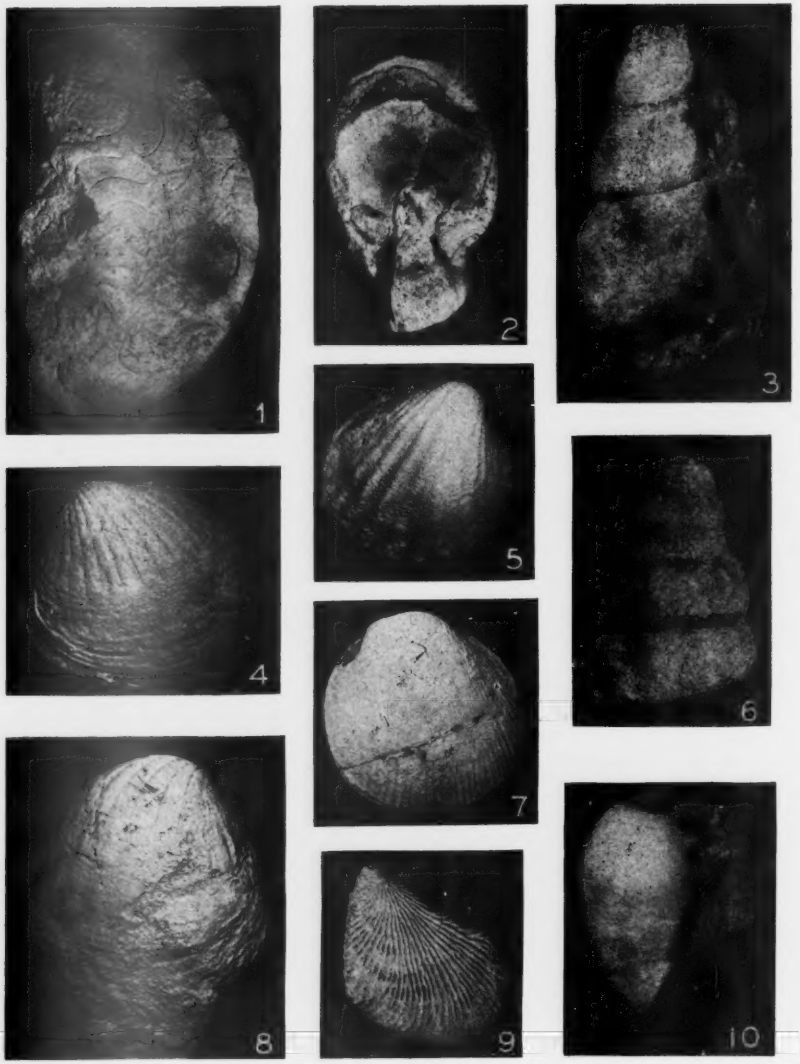


PLATE 7

Cretaceous, Paleocene and Eocene fossils.

FIGS. 1, 2.—*Hercoglossa* sp. LOC.: W. side small quebrada 880 meters S. 40° E. of Well Sibucara-4, Cojoro structure, Cañada Honda area, Dist. of Maracaibo. Las Flores formation. Creole Ser. No. 3,430½; P.R.I. 20,135.

FIG. 3.—*Perucerithium* sp. LOC.: N. side of road between Puente Gomez and Casa de Zinc, 700 meters W. of junction with road to Chejendé. Thin layer coarse sandstone and fine conglomerate interbedded in highly dipping black shale. Trujillo formation. Creole Ser. No. 13,177; P.R.I. 20,174.

FIG. 4.—*Venericardia* (*Venericor*) *toasensis* Dusenbury n. sp. LOC.: 600 feet NW. of Las Playitas, N. shore Toas Island, Tablazo Bay, Lake Maracaibo, Dist. of Mara, Zulia. Guasare formation. Paratype. Creole Ser. No. 13,002; P.R.I. 20,155.

FIG. 5.—*Venericardia* sp. LOC.: Quebrada El Mene 1900 meters upstream from its junction with Río Negro, Dist. of Perijá, Zulia. Río de Oro member of Mito Juan formation. Creole Ser. No. 9,609, P.R.I. 20,151.

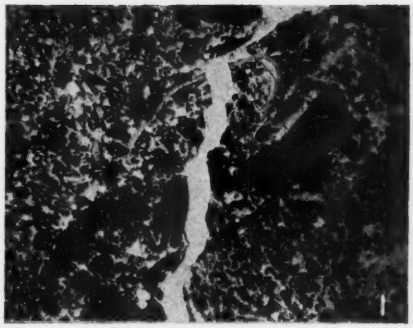
FIG. 6.—*Potamides* (*Telescopium*) sp. LOC.: Same as Fig. 3. Trujillo formation. Creole Ser. No. 13,177; P.R.I. 20,173.

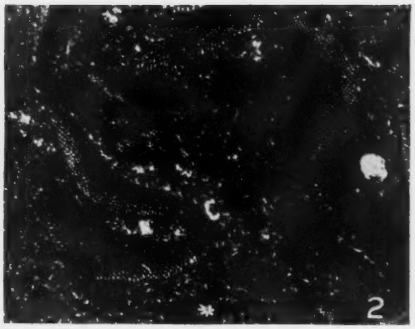
FIG. 7.—*Cardium* sp. LOC.: On N. side of highway 150 meters E. of Puente Gomez, Río Carache, Dist. of Carache, Trujillo. Misoa formation. Creole Ser. No. 9,306; P.R.I. 20,137.

FIG. 8.—*Venericardia* (*Venericor*) *toasensis* Dusenbury n. sp. LOC.: Same as Fig. 4. Guasare formation. Holotype. Creole Ser. No. 13,002; P.R.I. 20,155.

FIG. 9.—*Ostrea tacalensis* Hodson. LOC.: Same as Fig. 1. Las Flores formation Creole Ser. No. 3,430½; P.R.I. 20,125.

FIG. 10.—*Cypraea* sp., cast. LOC.: Same as preceding. Las Flores formation. Creole Ser. No. 3430½; P.R.I. 20,127.





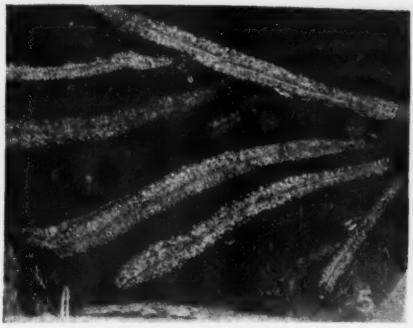


PLATE 8

Thin sections of Cretaceous and Paleocene limestones.

FIG. 1.—Cretaceous limestone with *Orbitolina concava* var. *texana* (Roemer). LOC.: Near base of formation on Caño Grande, branch of Río Cachirí, Dist. of Maracaibo, Zulia. Apón formation. Creole Ser. No. 13,119; P.R.I. 20,116.

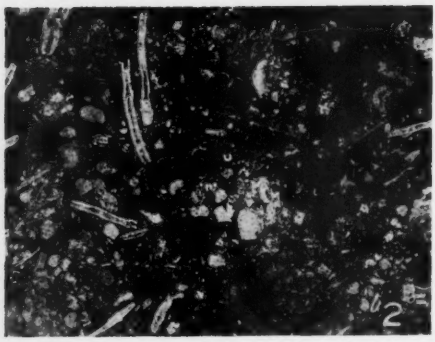
FIG. 2.—Cretaceous limestones with abundant *Orbitolina concava* var. *texana* (Roemer). LOC.: E. end of quarry of Caribbean Petr. Co. on W. end of Toas Island, Tablazo Bay, Lake Maracaibo, Dist. of Mara, Zulia. Apón formation. Creole Ser. No. 13,001; P.R.I. No. 20,115.

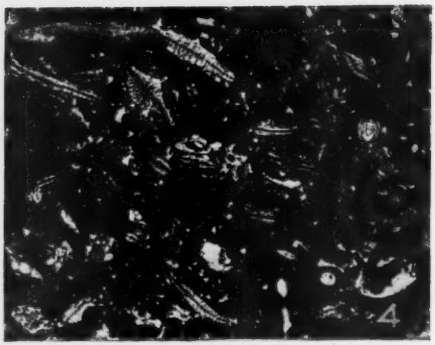
FIG. 3.—Upper Paleocene limestone with *Ranikothalia antillea* (Hanzawa), *Ranikothalia soldadensis* (Vaughan and Cole), *Discocyclina aguerreverei* Caudri, *Lepidorbitoides* cf. *planasi* Rutten of Caudri, *Lithothamnium* sp. LOC.: SE. side of road between Casa de Zinc and La Cuchilla 50 meters up road from small shrine 1.9 km. NE. Casa de Zinc, Dist. of Carache, Trujillo. Guasare formation. Creole Ser. No. 13,179; P.R.I. 20,118.

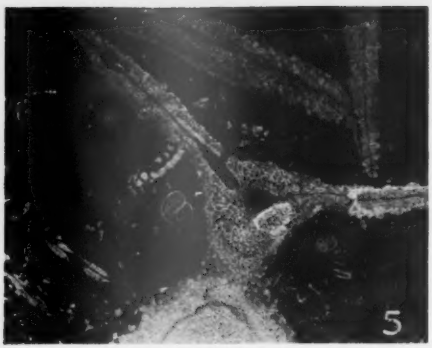
FIG. 4.—Same as last.

FIG. 5.—Upper Paleocene limestone with *Discocyclina* sp., *Lithothamnium* sp. LOC.: From bed of orbitoidal limestone about 1½ feet thick cropping out mainly as row of boulders along N. side of hill and 35 feet above base of formation, NW. of main highway to La Cuchilla, 900 meters NE. of Casa de Zinc, Dist. of Carache, Trujillo. Guasare formation. Creole Ser. No. 9,293; P.R.I. 20,113.

FIG. 6.—Same as last.







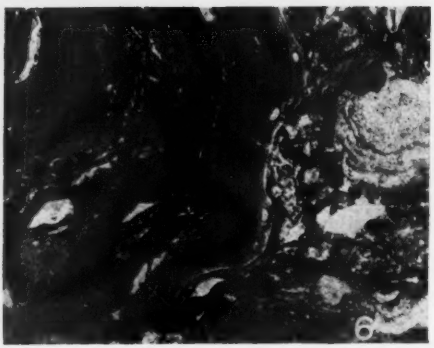


PLATE 9

Thin sections of Paleocene and Upper Eocene limestones.

FIG. 1.—Upper Eocene limestone with *Discocyclina* sp. and *Operculinoides soldadensis* Vaughan and Cole. LOC.: Beneath lowest sandstone ledges of Misoa formation on N. side of road between Puente Gomez and Casa de Zinc, 1.65 km. W. of junction with road to Chejendé, Dist. of Carache, Trujillo. Misoa formation, Cuicas limestone member. Creole Ser. No. 13,137; P.R.I. 20,117.

FIG. 2.—Upper Eocene limestone with *Discocyclina* sp., *Operculina* sp., *Rupertia* sp., *Tubologenerina* sp., *Globigerina* sp. LOC.: Small steep quebrada W. of sharp curve 1.8 km. from Cuicas on road connecting Cuicas with main Carache Valley road, Dist. of Carache, Trujillo. Misoa formation, Cuicas limestone member. Creole Ser. No. 9,295; P.R.I. 20,114.

FIG. 3.—Upper Eocene limestone with *Lepidocyclina* (*Polylepidina?*) *churuguaritana* Hodson, *Lepidocyclina* (*Pliolepidina*) *pustulosa* Douvillé, *Lepidocyclina* (*Pliolepidina*) *aurarensis* Hodson, *Operculinoides* sp., *Discocyclina* (*Asterocyclina*) sp., *Rupertia* sp., *Textularia* sp., *Lithothamnium* sp. LOC.: 7.45 km. S. 30° W. from La Victoria Well No. 1 and 2.5 km. NE. Río Aurare, Dist. of Miranda, Zulia. Churuguarita formation. Creole Ser. No. 2,684; P.R.I. 20,111.

FIG. 4.—Same as last.

FIG. 5.—Upper Eocene limestone with *Discocyclina* sp., *Operculina* sp., *Rupertia* sp., *Tubulogenerina* sp., *Globigerina* sp. LOC.: Same as Fig. 2. Creole Ser. No. 9,295; P.R.I. 20,114.

FIG. 6.—Upper Paleocene limestone with *Ranikothalia antillea* (Hanzawa), *Eorupertia* sp., *Lithothamnium* sp. LOC.: 900 meters NE. Casa de Zinc on crest of ridge NW. of road to La Cuchilla, Dist. of Carache, Trujillo. Guasare formation. Creole Ser. No. 9,291; P.R.I. 20,112.

Age and paleontology.—Fossil evidence from a number of localities in the Mérida Andes establishes an unquestioned late Carboniferous to early Permian age for the Palmarito.

Kehrer (1938, pp. 51–52) lists a large collection of Pennsylvanian and Permian fossils collected from Christ's type locality, stating that the Pennsylvanian ones were obtained from the anticlines of the section, while the Permian ones were gathered in the synclines. There are therefore at least two distinct formations in the type section. Collections made by P. P. Wolcott (unpublished report) from Christ's type locality contain *Productus*, *Chonetes*, and terebratuloids, while J. W. Nance (unpublished report) collected crinoid stems, *Fenestella*, and *Productus* from the lower part of the "Old Red" (Palmarito) series in the Río Boconó, State of Barinas. Thin sections of limestone from both localities show the presence of fusulinids.

The abundant crinoid stems and rare, poorly preserved brachiopods and bryozoans in the limestone on the Caño del Norte branch of the Río Cacharí are not sufficiently diagnostic in themselves for a reliable age determination. However, R. A. Rank collected and F. Hodson identified fusilinids from the Caño del Oeste branch of the Río Cachirí and from the Caño Pescado tributary of the Río Palmar (unpublished report). Unfortunately, these specimens were later lost in a laboratory fire.

Correlation.—The Mérida formation, referred to by Kündig (1938, p. 24), can also be correlated with the Palmarito from fossil evidence (unpublished Creole report) according to Olsson. Trümpy (1943, p. 1295) lists a Pennsylvanian fauna from Labateca, Colombia, and a Permian (Leonard) fauna in the Palmarito series on the west side of the Perijá Range in a fault block east of Manaure, Colombia. Part of Liddle's "Old Red Sandstone Series" belongs in the Palmarito, the rest in the younger La Quinta.

MESOZOIC

TRIASSIC

LA QUINTA FORMATION (UPPER TRIASSIC)

The name La Quinta was introduced by Kündig (1938, pp. 31–36) to describe a series of shales, sandstones, and conglomerates which crop out at the settlement of La Quinta, 3.5 kilometers west of the town of La Grita on the Transandean Highway in northeastern Táchira. The name is appropriate in view of the excellent exposures at and near the type locality.

Lithology.—The formation is predominantly red in color and is composed of intercalated shales and sandy shales, sandstones, and conglomerates. The conglomerates, which generally occur in the basal part of the section, are thickly bedded to massive, indurated, and gray to red in color. Schaub (1944) notes the presence of pebbles of fusulinid limestone derived from the Palmarito formation in the basal conglomerate of the La Quinta on the Trujillo-San Lázaro road in central Trujillo. The sandstones are brick red, micaceous, fine- to medium-grained, poorly bedded to massive, and cross-bedded. In some places the sandstones are

gray to green with red splotches. The shales and sandy shales are predominantly red, micaceous, and fissile, with subordinate amounts of gray and green. Samples of the sandstones that have been processed for minerals show a characteristic flood of hematite. An abundance of mica is present in some members.

The formation exhibits a continental to near-shore type of sedimentation. Dikes, lenses, and sills of diorite porphyry, quartz diorite porphyry, and vitrophyric diabase locally penetrate it in Mérida and Táchira.

Thickness.—The thickness of the La Quinta formation varies extremely over short distances. Kündig reports approximately 3,500 meters (11,482 feet) of these sediments in the Zumbador region of northwestern Táchira. This is probably the maximum for western Venezuela.

Stratigraphic relationship.—Major unconformities exhibiting angular discordance are present at both the top and bottom of the La Quinta formation. In the vicinity of the type locality, the formation rests on folded, metamorphosed gray schists which probably belong to the lower part of the Palmarito series. Throughout most of Táchira and Mérida, where its section is best developed, the La Quinta is almost everywhere in contact above with the coarse sands and conglomerates which generally characterize the initial Cretaceous deposition.

Distribution.—The distribution of the La Quinta formation is very irregular and its outcrop areas are generally limited to the mountain regions, where it is in close association with Cretaceous or Paleozoic rocks. In the Mérida Andes its best development occurs in southern Mérida and western Táchira. In the Sierra de Perijá on the west side of Maracaibo basin a coarse conglomeratic facies has been noted on the Río Aponcito Seco and the Río Macoita northwest of Machiques. In eastern Colombia the formation is present in the Santander region.

Age and paleontology.—Scarcity of fossils and lithologic similarity with both older and younger formations led early observers to assign ages to the La Quinta ranging from Devonian to Lower Cretaceous. However, from fossil evidence collected from the type locality and adjacent areas it has been possible to limit the age of these sediments to the period extending from the Middle Triassic to Lower Jurassic, with a suggestion that the range may be further limited to the Upper Triassic. The approximate true age of the formation was first published by Kündig (*op. cit.*). He collected an assortment of fish bones, scales, and teeth from the type exposure which were reported by A. S. Woodward as belonging to a "genus of ganoid fishes which cannot be distinguished from the European Jurassic and Rhaetic *Lepidotus*. The premaxilla and the fragment of the palate indicate a primitive species of the Upper Triassic to Lower Jurassic." A. A. Olsson has reaffirmed this age determination by additional paleontological evidence. At Celensio (near Hacienda Montaña) and along the trail in the upper part of the Potosí valley of southern Mérida, Olsson and Dallmus (unpublished Creole report) obtained a fauna from black shales in the upper part of the La Quinta which, according to Olsson, contain microscopic types of Crustacea, including small fresh-water ostracods and phyllopods. The most conspicuous and important fos-

sils in the black shale are the bivalved carapaces of the phyllopod *Estheria*. According to Olsson, the genus is known in beds from Devonian to Recent but the specific characteristics strongly resemble those of Upper Triassic forms from India, Argentina, and Colombia. At the present time Olsson's Upper Triassic age determination has been accepted for the formation. The ammonites and *Halobia?* sp. reported by Kehrer (1938, p. 53) from near Mucuchachí were also probably obtained from this formation and provide confirmation of Olsson's determination.

Correlation.—The first reference to the La Quinta formation was probably that of Sievers in 1889 who used the name "Lagunillas conglomerates" for a series of red conglomerates exposed near the town of Lagunillas in central Mérida. He was probably referring in part to the Dividive gravels which are composed largely of La Quinta float. There is also a suggestion that he may have mistaken the true La Quinta formation for beds of the Cretaceous. Before Kündig's use of the name "La Quinta," the formation was generally referred to as the Girón series, a name which was first applied by Hettner (1892) to a red sandstone formation in Colombia. The Girón was later confused with the Lower Cretaceous Arcabuco, Salina, and Caqueza formations, which are correlative with the Río Negro formation of the Maracaibo basin. Recently, Olsson has found black shales containing *Estheria* not far from Girón, and it thus appears that the former correlation of the La Quinta with the Girón is probably correct.

The Seco conglomerate, which crops out as a narrow belt of limited extent along the eastern front of the Sierra de Perijá, is believed to be correlative with the La Quinta formation. It is best exposed on the Quebrada Aponcito Seco to the northwest of Machiques in the Perijá District of western Zulia. At this point it attains its maximum noted thickness of 670 meters (2,198 feet) and is described as a dull reddish black or gray, hard, very coarse, massive, cobblestone conglomerate. It is unconformable with the Devonian (Macoita formation) below and the basal sandstones and conglomerates of the Cretaceous above. The cobblestones are in part igneous and in part derived from the underlying Devonian. The formation thins in a short distance northward and dies out before reaching the Cogollo River. Its southern extent is not known, but it was observed to occur in the Río Macoita section.

The red conglomerates, sandstones, and sandy shales termed the Lomita series by Christ (1927, p. 398) definitely belong to the La Quinta as does also the Río Masparro formation described by Mackenzie (1937, p. 260). The type section of the Lomita is on the Santa Bárbara-Mucuchachí trail in southern Mérida, that of the Río Masparro is along the river of the same name in the State of Barinas.

CRETACEOUS

Rocks of Cretaceous age are distributed widely around the margins of the Maracaibo basin in the states of Zulia, Táchira, and Mérida. They are particularly well developed in the eastern foothills of the Perijá Range, from which many

of their formational and group names, such as the Río Negro, Cogollo, and La Luna were selected. They have, also, an important development in Táchira, where the type localities for the Colón and Capacho formations occur. Southwest the Cretaceous zone extends into northeastern Colombia (Santander del Norte) and here the type section of the Mito Juan formation is found.

In the earlier geological studies in the Maracaibo basin, and elsewhere in Venezuela, formational names were used broadly and correlation between sections was based mainly on lithologic resemblance or general succession. In recent years, however, information on the paleontology of the Venezuelan Cretaceous and the range of its principal or diagnostic species has grown steadily, permitting closer age determinations and correlations among separated areas. These studies have revealed that correlation on lithology alone is not always certain and that some beds, such as the Cogollo limestones, may include rocks of widely different ages. The following discussion does not pretend to be a final solution of the Cretaceous problem in the Maracaibo region but merely records our present interpretation. Future paleontological discoveries will probably result in further revisions. Established names in current use have been retained, although they are used in some instances in a restricted sense.

RÍO NEGRO FORMATION (LOWER CRETACEOUS)

The term Río Negro, first published by Hedberg (1931, p. 230), has been used for many years to describe a thick conglomeratic sandstone formation which is exposed along the Río Negro in western Perijá District, where this river cuts through the eastern foothills of the Sierra de Perijá. The name has been applied by some geologists to any sandstone or conglomeratic zone at the base of the Cretaceous sequence in other parts of the basin, but in the present paper, it is restricted to the vicinity of the type locality.

Lithology.—In the type section, the formation is composed of coarse, gray to light gray, thick-bedded arkosic sandstones which contain many irregular beds and lenses of pebble conglomerate. The pebbles are generally white vein quartz and few exceed one inch in diameter. In its extreme upper part the formation is slightly calcareous. Hedberg and Sass (1937, p. 76) report a simple heavy-mineral suite characterized by an abundance of polished zircon and a scarcity of black opaques.

Thickness.—No report on the actual thickness of the formation is available for the type section but Hedberg and Sass (*op. cit.*) estimate about 3,000 meters (9,843 feet). The formation probably attains its maximum development in this area, with thinning both north and south. On the Río Yasa, 14 kilometers south of the type section, it has a thickness of 1,200 meters (3,937 feet) and on the Río Apón, 6 kilometers north of the type exposure, a thickness of 2,830 meters (9,285 feet) has been measured.

Stratigraphic relationship.—At its base the Río Negro conglomerate is always unconformable and probably exhibits angularity with older formations. Above, it is gradational into fossiliferous Cretaceous.

Distribution.—The Río Negro formation, as here understood, is restricted to its type area in the central part of the Perijá Range. It extends westward into the adjacent part of Colombia (César basin) and probably continues eastward for a considerable distance beneath Lake Maracaibo.

Age and paleontology.—No fossils are known from the Río Negro beds proper so that a direct age assignment on the basis of paleontology is at present impossible. At the type locality the formation is overlain by fossiliferous limestones and shales of Aptian and probably, in part, Barremian age. Therefore, the type Río Negro is at least as old as Barremian and probably older. Rocks which are lithologically similar to the Río Negro, and appear to occupy the same position in the section, are present in the César basin of Colombia where they underlie beds with typical Barremian fossils.

Correlation.—The Río Negro is believed to be correlative with the Arcabuco and Caqueza quartzites of Colombia on the basis of lithology and stratigraphic position. The Caqueza is interbedded with fossiliferous shales of Berriasian, Valanginian and Hauterivian age.

On the basis of lithology alone, the Río Negro could be correlated with the other sandstones and conglomerates which initiated the Cretaceous deposition throughout the entire Maracaibo basin. From the viewpoint of cyclical deposition and age, however, the correlation is not valid, since the formation ascends the time scale and crosses age boundaries outward from the deeper parts of the Machiques trough. Thus, the type Río Negro underlies probable Barremian; the "Río Negro" of the Río Cachirí section (Liddle, 1943, p. 27) and Toas Island underlies upper Aptian; the Tomón formation (Kehrer, 1937, p. 52) and the Uribante formation (Sievers, 1888, p. 19; Notestein, Hubman, and Bowler, 1944, pp. 1173–78) contain Aptian and Albian fossils and underlie the Cenomanian.

The Río Negro formation is probably roughly equivalent to the Barranquín formation of eastern Venezuela.

COGOLLO GROUP (MIDDLE CRETACEOUS)

The name Cogollo formation, was first introduced into the geological literature of Venezuela by Garner (1926, p. 679) and was soon generally adopted by most geologists to designate a predominantly limestone deposit lying beneath the bituminous shales and limestones of the La Luna, and above the basal sandstones of the Cretaceous. In its type exposure along the Río Cogollo and in the general zone along the east side of the Perijá Range, the Cogollo is now known to include rocks which range in age from probable Barremian through Aptian and Albian to Cenomanian. The name has been a convenient one for reconnaissance mapping and its long established use in Venezuelan geology demands its retention. In this paper it will be used as a group term.

The resistant limestones of the Cogollo group, which weather light gray in color, form prominent, easily recognized scarps along the mountain front and, in some of the streams cutting them, form high, vertical or overhanging walls. The

shales, being less resistant, have generally weathered out or are so covered with soil or talus that a casual inspection of the section gives the erroneous impression that the entire group is practically solid limestone.

The Cogollo group may be divided into two major parts, usually separated by a zone of glauconitic sandstone which, in reality, pertains to the upper division and generally represents the initial sedimentation of the Cenomanian depositional cycle. In the present review, the lower division of the Cogollo group is referred to as the Apón formation while the upper division has been subdivided into a lower Aguardiente formation and an upper Capacho formation. These will be discussed separately.

APÓN FORMATION: LOWER COGOLLO (MIDDLE CRETACEOUS)

The name Apón is derived from the Río Apón in western Perijá District, Zulia, and is introduced at this time to designate the predominantly limestone basal division of the Cogollo group. The formation is well exposed along the river's course, about 10 kilometers west from Machiques, where the stream cuts through the eastern foothills of the Perijá Range. The base of the formation is readily apparent where it is in contact with the underlying sandstones and conglomerates of the Río Negro formation.

Lithology.—The Apón formation of the type section and adjacent areas is composed of thick-bedded, light gray to gray and blue-gray, hard, dense, locally fossiliferous limestone interbedded with subordinate amounts of dark gray calcareous shale and sandy shale. Here and there, beds of black shaly limestone and calcareous sandstone are present. On the Río Negro, about 6 kilometers south of the type exposure, is a 50- to 75-foot interval in the middle part of the formation which is composed of black calcareous shale and thin platy limestone. It carries an abundance of discoidal and ellipsoidal, black, fossiliferous limestone concretions ranging from a few inches to 18 inches in diameter. Lithologically, this concretionary member is very similar to the younger La Luna formation and confusion between the two might easily result for one not thoroughly familiar with the section. On paleontological evidence the difference is readily apparent.

The common sedimentation of the Apón limestones is shallow marine, as indicated by the abundance of thick-shelled types of mollusks. Change to shale deposition with ammonites ordinarily indicates a deeper-water type of deposit.

Thickness.—The thickness of the formation at the type exposure is about 650 meters (2,133 feet), and on the Río Cachirí, 95 kilometers (59 miles) north, it measures approximately 510 meters (1,673 feet). Along the Carache River Valley of northeastern Trujillo, 250 kilometers (155 miles) southeastward across the basin, the formation has a thickness of about 600 meters (1,969 feet). Here it is composed largely of medium- to coarse-grained sandstones with a few thin beds of limestone (Tomón formation of Kehrer). Southward, along the southeastern rim of the basin the formation thins appreciably and, in Mérida and Táchira, does not exceed 300 meters (984 feet) in thickness. Farther southwest, in the

Barco area of Colombia, Notestein, Hubman, and Bowler (1944, pp. 1174–78), report a thickness of 256 to 367 meters (840 to 1,204 feet) for the equivalent interval.

Stratigraphic relationship.—In the deeper parts of the Machiques trough the Apón formation is conformable and probably gradational with the underlying Río Negro formation. Out toward the edges of the Cretaceous basin, however, it may be found in unconformable contact with beds ranging from the Triassic to pre-Cambrian.

The Apón is believed to be overlain everywhere by the Aguardiente formation, although the latter is in many places so poorly developed that it may escape detection.

Distribution.—The Apón formation is widely distributed throughout western Venezuela and eastern Colombia, and its exposures are generally found occupying continuous belts along the eastern front of the Sierra de Perijá and northwestern front of the Mérida Andes. It is prominently exposed on Toas Island in Tablazo Bay, north of Maracaibo. The formation is believed to underlie almost the entire Maracaibo basin, although there is some subsurface evidence to indicate that it may not have been deposited over parts of the high basement area in the Districts of Mara and Maracaibo, Zulia.

Age and paleontology.—The Apón formation contains a characteristic lower Middle Cretaceous fauna in which ammonites, caprinids, *Requienia*, *Exogyra*, *Nerinea*, and *Orbitolina* are the commonest types. These fossils indicate a time range extending from upper Aptian to middle Albian. Below the upper Aptian ammonite horizon on the Río Negro occur massive limestones, apparently unfossiliferous except for *Panope plicata* Sowerby in a zone near the top, which closely resemble in lithology and stratigraphic position limestones bearing Barremian fossils on the Colombian side of the Sierra de Perijá. Ammonites, rare in the calcareous facies, are locally common in the shales and concretions. From the Venezuelan side of the Perijá Range several characteristic upper Aptian species have been obtained which belong to the genera *Cheloniceras*, *Parahoplites*, *Deshayesites*, *et cetera*. This assemblage is well known at many places in Colombia.

From the Apón outcrops on Toas Island, A. N. Dusenbury (unpublished report) has identified the following fossils.

Quinqueloculina sp.
Triloculina sp.
Spiroculina sp.
Orbitolina concava var. *texana* (Roemer)
Ostrea sp.
Ostrea (*Gryphaeostrea*) sp.
Exogyra boussingaulti d'Orbigny
Requienia sp., fragment
Amphitriscoelus waringi Harris and Hodson
Cheloniceras sp.
Parahoplites sp.

From the lower part of the Apón section on the Caño Grande branch of the Río Cachirí, Dusenbury has identified *Orbitolina concava* var. *texana* (Roemer).

From the middle part of the Apón section on the Río Cogollo and the Quebrada La Luna, specimens of a rather abundant tubular fossil tentatively identified as *Polorthus* were collected.

From the upper part of the Apón section on the Río Cogollo, Dusenbury has identified the following echinoids of probable middle Albian age.

Phymosomas cf. *texanum* (Roemer)
Holectypus sp.
Hardouinia? sp.

A. A. Olsson (unpublished report) has identified the following upper Aptian species collected from the limestone concretions of a black shale member in the middle of the Apón formation on the Río Negro.

Deshayesites cf. *stutzeri* Reidel
Parahoplites cf. *inconstans* Reidel
Cheloniceras cf. *cornueli* d'Orbigny

From Apón formation float in the Río Cogollo, Olsson identified

Deshayesites cf. *columbianus* Reidel.

From a collection made by Wolcott at a locality in Trujillo 1½ kilometers west of the junction of the Escuque-Mendoza Fría road, V. Winkler (unpublished report) identified the following.

Orbitolina concava var. *texana* (Roemer)
Enallaster texanus Roemer
Echinoids
Barbatia sp.
Cucullaea sp.
Ostrea sp.
Gryphaea sp.
Trigonia sp.
Neithea quinquecostata Sowerby var. *morrisi* Pictet and Ren.
Neithea sp., cf. *texana* (Roemer)
Pholadomya nodulifera Muenster
Liopistha sp.
Caprinids
Protocardia sp.
Isocardia sp.
Mactra sp., cf. *peruana* Steinmann
Tylostoma sp., cf. *T. pedernales* Roemer
Natica sp., cf. *N. bulbiformis* Sowerby
Cephalopod

Liddle (1928, p. 150) lists among others the following from the Quebrada La Luna and Río Apón.

Gryphaea cf. *washitaensis* Hill
Exogyra boussingaulti d'Orbigny
Exogyra weatherfordensis Cragin
Ostrea sp., aff. *O. johannae* Choffat
Pecten irregularis Böse
Cyprimeria texana Roemer
Exogyra cf. *E. americana* Marcou
Enallaster sp.

Correlation.—The Manantiales limestone of Garner (1926, p. 679) is equivalent to the Cogollo group, but the correlation with the different formations of the group has not yet been attempted. The type locality is near the village of Manantiales at the northeastern extremity of the Montes de Oca, a range of the north end of the Sierra de Perijá, in the western part of the District of Paez, Zulia.

The Cachirí limestone of Garner (1926, p. 679) was described from an incomplete section of the Cogollo group with fault contacts above and below, and here also correlation with the different formations of the group has not yet been attempted. The type section is on the Río Cachirí where the river passes between Cerro los Guineos and the Sierra de Cachirí slightly upstream from Rancho Cachirí.

Higher up the same river on the opposite or western side of the Manuelote syncline a complete Cogollo section including all three formations can be observed. Garner's Middle Cretaceous Cachirí limestone should not be confused with Liddle's Devonian Río Cachirí group previously mentioned in this paper.

The combined Tibú and Mercedes members of the Uribante formation, as described by Notestein, Hubman, and Bowler (1944, pp. 1174–78), represent the equivalent of the Apón formation in the Barco Concession. The Uribante beds near the Santo Domingo bridge over the Río Uribante in Táchira, said by Kehrer (1937, pp. 66–67) to contain *Gümbelina* and *Choffatella*, and the *Orbitolina* beds southeast of Pregonero (*idem*) are both correlative with the Apón formation.

Wolcott's previously mentioned collection of fossils from the locality on the Escuque-Mendoza Fría road and the occurrence, described by Tomalin (1938, p. 19), of *Orbitolina concava* var. *texana* (Roemer) and *Choffatella* sp. in the limestone beds near the base of the Tomón formation in the Río Carache section, Trujillo, demonstrate that the lower part of the Tomón formation of Kehrer (1937, pp. 54–69; 1938, p. 239, Spanish edition only) is correlative with the Apón formation of the Cogollo group and with the Tibú and Mercedes members of the Uribante. The Playa Grande sandstone (Kehrer, 1937, p. 54) of the area north of San Simón and Zea in southwest Mérida is a local name for the Tomón. The type locality of the latter is along the trail passing over the Alto de Tomón between Monte Carmelo and Mendoza Fría in the State of Trujillo. A fair section of metamorphics, Tomón, upper Cogollo, La Luna, Colón, and Misoa can be seen as one climbs from Mendoza Fría to the summit of the Alto de Tomón.

The combined El Cantil, Chimana, and Bergantín formations of eastern Venezuela and the *Orbitolina* limestones of Trinidad are additional correlatives of the Apón formation.

AGUARDIENTE FORMATION: UPPER COGOLLO (MIDDLE CRETACEOUS)

The name Aguardiente was introduced by Notestein, Hubman, and Bowler (1944, p. 1177) to describe an essentially glauconitic sandstone formation that is prominently exposed on the Filo del Aguardiente, an impressive topographic feature immediately adjacent to the southern boundary of the Barco Concession of Colombia. In their excellent report on that area the authors have noted the two major divisions of this paper's Cogollo group and have considered the Aguardiente to be the uppermost member of the lower division (Uribante). It seems more logical, however, to assign the Aguardiente formation to the basal part of the upper Cogollo.

Lithology.—According to Notestein *et al.*, the Aguardiente formation of the type locality,

> is composed almost entirely of extremely hard and calcareous gray or light green fine- to coarse-grained cross-bedded glauconitic sandstones. Interbedded with the more glauconitic sandstones are gray, only slightly glauconitic sandstones with micaceous-carbonaceous partings. Some thin laminae and beds of black micaceous-carbonaceous shale are present, and a few thin beds of limestone occur in the lower part. Locally the sandstones are so calcareous as to approximate arenaceous limestones."

This description generally holds throughout the basin, although there is marked variation in the degree of glauconitization among different areas.

Thickness.—From well sections and the Quebrada Santa Elena in the Barco area, Notestein *et al.* report a thickness of 148 to 160 meters (486 to 525 feet) for the Aguardiente and indicate that it is considerably thicker to the south in the vicinity of the type locality. It reaches its maximum development along the northwestern slope of the Mérida Andes in the State of Táchira, and on the Río Omuquena in the north-central part of the state measures 530 meters (1,739 feet) in thickness. It thins in a short distance northward from this area, and on the Río de Oro of northern Táchira and Río Buena Vista of southwestern Trujillo it is 330 meters (1,083 feet) and 260 meters (853 feet), respectively. In northern Trujillo the thickness probably does not exceed 50 meters (165 feet)). Along the western rim of the basin in the northern Perijá Mountains, the formation is poorly developed and its thickness does not exceed 15–20 meters (50–66 feet). In many places its presence can be verified only by careful investigation.

Stratigraphic relationship.—A disconformity has been postulated between the Aguardiente and the underlying Apón formation. Although positive evidence is lacking, this relationship is suggested by the abrupt change in the type of sedimentation and the belief by some investigators that a considerable portion of the upper Albian is missing from the section.

The Aguardiente is everywhere conformable and gradational with the overlying Capacho formation.

Distribution.—The Aguardiente formation is distributed widely throughout western Venezuela and eastern Colombia, and its exposures are present along the entire eastern front of the Sierra de Perijá and northwestern front of the Mérida Andes. It attains its maximum development in the south-central part of the basin and is believed to underlie the entire basin.

Age and paleontology.—Fossils are ordinarily scarce in the Aguardiente formation. Notestein, Hubman, and Bowler (*op. cit.*, p. 1178) mention molds of *Exogyra* and other Cretaceous Ostreidae. Fragments of a large flat oyster commonly occur in a thin layer at the top of the formation in the area extending from the Río Cogollo to the Río Cachirí. These fossils are too imperfectly preserved to make a direct age determination of the formation, which has nevertheless been tentatively referred to the upper Middle Cretaceous (Cenomanian) and is believed to be of the same general age as the Woodbine and Dakota sands of North America. It marks the beginning of the Gulfian depositional cycle.

Correlation.—Approximate equivalents of the Aguardiente formation are the Sabaneta formation of Oppenheim (1937, p. 40) in southern Mérida, the Calderas formation of Mackenzie (1937, pp. 260–61) in Barinas, the upper part of the Playa Grande sandstone of Kehrer (1937, p. 54) in southwestern Mérida, the upper part of the Tomón formation of Kehrer (1937, p. 52) in Trujillo, and the Nevada, Cocuy, and Uné formations of Colombia.

CAPACHO FORMATION: UPPER COGOLLO (MIDDLE CRETACEOUS)

The term Capacho was introduced by Sievers (1888) to designate the Cretaceous limestones and shales which crop out near the town of Capacho (now called Independencia) in western Táchira. Liddle (1928, p. 124) later used the name, but in a broader sense, and included within his Capacho series all of the formations of the Cogollo group of the present study. The name is used here in its original sense and applies only to the formation represented at the type exposure.

Lithology.—Structural complications hinder an accurate description of the entire Capacho formation at the type locality. In the Río de Oro in northern Táchira, however, a complete section is exposed between the overlying La Luna and underlying Aguardiente formations. At this point the formation can be divided roughly into a lower and upper member. The lower member has a thickness of about 242 meters (794 feet) and is composed largely of massive, dark gray to black hard shale with a few beds, up to one meter thick, of dark gray, hard, crystalline, fossiliferous limestone and rare beds of dark greenish gray, hard, fine-grained, calcareous sandstone. The calcareous sandstones are generally more pronounced in the basal part of the formation and some observers may wish to include them with the underlying Aguardiente formation. The upper member is about 120 meters (394 feet) thick and is composed of massive to thickly bedded, gray, hard, crystalline, fossiliferous limestone with a few thin beds of hard black shale. Good exposures of this member are present also on the Río Escalante, Río Omuquena, and Río Lobaterita of southwestern Mérida and western Táchira. The limestones of both members generally emit a strong petroleum odor when freshly broken. It is generally not possible to subdivide the Capacho. In most places its lithology is similar to that exhibited by the upper member of the formation on the Río de Oro. The heavy-mineral recovery from the sandstones is relatively poor and non-diagnostic. The type of sedimentation of the formation is shallow to deeper marine.

Thickness.—In Táchira, on the northwestern slope of the Mérida Andes, the Capacho formation varies in thickness from 240 meters (787 feet) in the Río Omuquena to 310 meters (1,017 feet) in the Río de Oro. It thickens northeastward and in the Carache Valley of Trujillo is approximately 460 meters (1,509 feet). Northwestward across the basin, along the headwaters of the Río Cachirí in the Sierra de Perijá, it has a thickness of 223 meters (732 feet). Southward from this point it increases in thickness to approximately 400 meters (1,312 feet) in the Río Apón. Farther south in the Barco area of Colombia, Notestein, Hubman, and Bowler (1944, p. 1179) report thicknesses from well sections ranging from 175 to 273 meters (574 to 896 feet) and outcrop sections which measure up to 435 meters (1,427 feet).

Stratigraphic relationship.—The Capacho is gradational into the underlying Aguardiente formation and conformable with the overlying La Luna formation.

Distribution.—The Capacho formation is widely distributed throughout

western Venezuela and eastern Colombia. Its outcrops occupy continuous belts along the eastern front of the Sierra de Perijá and northwestern front of the Mérida Andes. It is believed to underlie the entire basin.

Age and paleontology.—An upper Middle Cretaceous (Cenomanian) age has been assigned to the Capacho formation. Its hard limestone members are generally fossiliferous but extraction of the specimens is usually extremely difficult. Cross sections and fragments show that the fossils consist primarily of species of *Plicatula, Exogyra, Trigonia, Cardita,* and *Ostrea.* Rare cross sections and fragments of ammonites have been observed also but proved to be unidentifiable. In the vicinity of Colón, Táchira, Kehrer (1937, p. 52) notes the presence of abundant "Cogollo" fossils, among which *Exogyra africana* Coquand, var. *peruana* is predominant. This variety occurs in the Cenomanian of Peru. Notestein *et al.* (*op. cit.*, p. 1182) list the following "Cogollo" fauna from the Barco Concession.

Cardita subparallela Gerhardt
Cyprimeria sp.
Poromya sp.
Plicatula "maraensis"
Corbula sp.
Gryphaea sp.
Inoceramus sp.
Trigonia sp.

From the upper part of the Capacho formation on the Río Apón, Olsson has identified the following two Cenomanian species.

Ostrea scyphax Coquand
Neithea aequicostata d'Orbigny

Correlation.—The Capacho is the equivalent of the "Cogollo" of Kehrer (*op. cit.*) in Táchira, Mérida, and Trujillo and of Notestein *et al.* in the Barco Concession. In these areas the "Cogollo" is restricted to the Cenomanian, while the type section on the Río Cogollo includes strata at least as old as upper Aptian.

LA LUNA FORMATION (UPPER CRETACEOUS)

The name La Luna was probably first published by Garner (1926, p. 679) to describe a limestone and shale formation exposed on the Quebrada La Luna in the District of Perijá, western Zulia, where this stream cuts through the foothills of the Sierra de Perijá.

Lithology.—The formation is of marine origin and is composed principally of hard, dark gray to black, carbonaceous, and bituminous limestone, in beds that generally do not exceed 20 centimeters in thickness, and interbedded, black, calcareous shale. Subordinate amounts of hard, fine-grained, dark gray, calcareous sandstone, and seams and nodules of chert are present. Characteristic of the formation are discoidal concretions of hard, black, limestone which range in size from a few centimeters to one meter in diameter. These concretions commonly contain megafossils, such as ammonites, and some contain drops of live oil. When freshly broken the limestone members of the formation generally emit a strong petroleum odor. The formation is almost barren of heavy minerals although some black and yellow opaques, such as pyrite, are present.

Thickness.—The thickness of the formation in the type section is about 300 meters (984 feet). On the Río Cachirí, 45 kilometers toward the north it is 180 meters (590 feet). With the exception of the type exposure, the thickness of the formation along the eastern front of the Sierra de Perijá nowhere exceeds 183 meters (600 feet). Southeastward across the basin in the Carache Valley of Trujillo, the thickness of the La Luna is 315 meters (1,033 feet) but decreases in a short distance southwestward along the basin-facing flank of the Mérida Andes. In the Río Buena Vista of southwestern Trujillo and Río de Oro of northern Táchira the thickness is 70 to 100 meters (230 to 328 feet) and 100 meters (328 feet), respectively. Westward, in the Barco Concession of Colombia, Notestein, Hubman, and Bowler (1944, p. 1182) report thicknesses of 43 to 56 meters (141 to 183 feet) in the southern part of the area and an average of 86 meters (282 feet) in the northern part.

Stratigraphic relationship.—There is no apparent discordance within the Maracaibo basin between the La Luna and underlying Capacho formations. Recent studies outside the basin however, have indicated clearly a disconformable relationship.

In its type section the La Luna rests unconformably beneath the Upper Eocene La Sierra sandstone. Elsewhere a disconformity is believed to be present between the La Luna and overlying Colón formation. Both are fossiliferous throughout and detailed paleontological studies have indicated that the entire Santonian stage is missing from the time scale.

Distribution.—The La Luna formation is distributed widely throughout western Venezuela and eastern Colombia. Its exposures occupy narrow belts along the entire basin fronts of the Sierra de Perijá and Andes de Mérida. It has been encountered in a number of exploratory wells in western Zulia and is believed to underlie the entire basin.

Age and paleontology.—The La Luna fauna is of a deeper-water type than that that of the underlying Capacho formation. The limestone concretions are especially fossiliferous and contain the best preserved molluscan specimens. The locally prolific fauna includes numerous ammonites, various species of *Inoceramus*, fish remains, and pelagic Foraminifera, and the formation as a whole is the most fossiliferous of the entire Cretaceous sequence in Venezuela. This same fauna is well known in Colombia and extends southward through the Andean geosynclines into eastern Ecuador and northern Perú. The Mollusca belong to three different faunal assemblages: lower Turonian, upper Turonian, and lower Coniacian in age. These have been intensively collected along the type section in the Quebrada La Luna. Above the lower Coniacian zone is a considerable section which contains no macrofossils. This has been arbitrarily assigned to the upper Coniacian until further information can be obtained.

It should be pointed out that many of the La Luna ammonites in previous collections have been obtained from loose concretions in fields, on talus slopes, or along watercourses, and their actual position in the section is known only ap-

proximately. To add to the confusion, a few of the fossils were improperly identified, so that some of the older faunal lists include Albian, Cenomanian and Santonian genera. Much work remains to be done on the zonation of the formation.

Collections made along the type section in the Quebrada La Luna have been studied by R. W. Imlay, A. A. Olsson, J. W. Durham, and A. N. Dusenbury. Some differences of opinion were expressed both as to the identification and the age determination of several of the species, but the known stratigraphic horizons from which the specimens were gathered and the associated fossils make it possible to resolve some of these disagreements.

Lower Turonian
Inoceramus labiatus Schlotheim
Eucalycoceras sp.
Prionotropis? sp. (Determination by Imlay and Durham)
Hoplitoides sp.
Barroisiceras (*Harleites?*) *subtuberculata* Gerhardt
Neoptychites sp.

Inoceramus labiatus is confined to the Turonian, and the range of *Eucalycoceras* is upper Cenomanian and lower Turonian. Both *Hoplitoides* and *Neoptychites* are diagnostic of the lower Turonian. *Prionotropis* also is confined to the Turonian, but in this case there is some doubt as to the proper identification, since *P. woolgari*, the type species, has a serrate triple keel, while the specimen examined for this report has a single, continuous, non-serrate ventral keel flanked on either side by a row of prominent tubercles which gradually develop into spines. The *Barroisiceras* from this horizon was identified by Olsson as *B. subtuberculata* Gerhardt (*Neophlycticeras?* of Reidel) and by Imlay as *B. Harleites?*) sp. The two independent determinations were combined in the foregoing faunal list. The ribs of the specimens examined are low, broad, rounded and slightly sigmoidal instead of narrow and gently arcuate as in typical *Harleites*.

Upper Turonian
Inoceramus sp.
Coilopoceras sp.
Discohoplites? cf. *subfalcatus* (Semenow) (Determination by Imlay)
Protacanthoceras? sp., cf. *Lyelliceras scheibei* Reidel (Determination by Imlay)

From this bed several specimens of *Coilopoceras*, a genus typical of the upper Turonian, were secured. The identification of the associated *Discohoplites?* and *Protacanthoceras?* seems highly questionable, as the former genus is usually regarded as restricted to the upper Albian and the latter is Cenomanian, while *Lyelliceras* is Albian in age.

Lower Coniacian
Didymotis variabilis Gerhardt
Peroniceras cf. *moureti* de Grossouvre
Barroisiceras (*Alstadenites*) cf. *sevierense* Reeside
Barroisiceras cf. *brancoi mile* Solger

The foregoing fauna from slightly above the middle of the type La Luna section is clearly lower Coniacian and is correlative with that of a similar horizon in Táchira.

Additional species from other representative localities along the eastern front of the Perijá Range have been identified as *Thomasites* sp. (Turonian) *Gauthiericeras* aff. *margae* Schlüter (Coniacian) and *Peroniceras* cf. *cañaense* (Gerhardt) (Coniacian).

Southward, at Borotá near San Cristobal in the State of Táchira, the La Luna has yielded fine specimens of both Turonian and Coniacian age. Olsson lists the following species, the majority obtained from loose limestone concretions scattered on the surface.

Turonian
Inoceramus labiatus Schlotheim
Inoceramus spp.
Coilopoceras sp.
Prionotropis sp.

Coniacian
Lenticeras andinii Gabb
Paralenticeras sieversi Gerth
Gauthiericeras cf. *lenti* Gerhardt

The following Coniacian species from Rubio in southwestern Táchira were illustrated and described by Gerhardt (1897–98).

Gauthiericeras margae Schlüter
Gauthiericeras lenti Gerhardt
Peroniceras cañaense (Gerhardt)
Texanites texanum (Roemer)

Correlation.—The La Luna is the equivalent of the Táchira formation (Hedberg and Sass, 1937, p. 81), usually spoken of as the Táchira cherts, in the State of Táchira, where a cherty facies commonly predominates. The Táchira cherts can be correlated with the Palmira cherts of Colombia, while the typical facies of the La Luna can be correlated with the Querecual formation (Hedberg, 1937, p. 242), forming the lower half of the Guayuta group in eastern Venezuela.

COLÓN FORMATION (UPPER CRETACEOUS)

The name Colón formation was introduced into the published reports by Liddle (1928, pp. 169–77), who was uncertain whether the term was taken from the District of Colón in southwest Zulia or from the town of Colón in Táchira. Hedberg and Sass (1937, pp. 81–82) report that the name was first applied by geologists of the Shell group of companies to outcrops on the Tarra anticline in the District of Colón. However, the section in the Río Lobaterita immediately north of the town of Colón, District of Ayacucho, Táchira, is so much superior that these authors recommended its use as the type.

Lithology.—At the type locality and, in fact, along the entire northwestern flank of the Mérida Andes, the formation is composed almost entirely of massive, dark gray to black, hard, locally pyritic, conchoidal to irregular-fracturing shale. In places some very thin beds of gray, hard, dense limestone are present in the upper part of the formation. Sandstones are rare, although on the Río de Oro some argillaceous sandstone is present near the base of the formation. In the Barco Concession area, Notestein, Hubman, and Bowler (1944, p. 1183) report a 2 to 5 meter zone of sandy glauconite near the base. The formation is abundantly foraminiferal.

Thickness.—In the type section the thickness of the Colón formation is 900 meters (2,952 feet). Notestein *et al.* report a thickness of 210 to 450 meters (689

to 1,476 feet) in the Barco area of Colombia. On the Río de Oro of northern Táchira the thickness is 370 meters (1,214 feet), and in the Carache Valley of Trujillo, 190 kilometers (118 miles) northeast the thickness is 400 to 500 meters (1,312 to 1,640 feet). Across the basin in western Zulia, along the Río Cachirí, the formation is 470 meters (1,542 feet) thick.

It is interesting to note that in areas where both the Colón and overlying Mito Juan formations are present, a change in thickness of one is generally compensated by a corresponding but opposite change in thickness of the other, with the total remaining fairly constant. This suggests that both formations are only different lithologic or facies expressions of the same depositional or time cycle.

Stratigraphic relationship.—No structural discordance has been observed between the Colón and underlying La Luna formation, but it is believed that a break in sedimentation occurred. The contact is generally well defined and detailed paleontological studies have indicated that all or part of the Santonian stage is missing from the time scale.

In normal sequence the Colón is transitional into the overlying Mito Juan formation, but where the latter is missing as a result of erosion or non-deposition, it is overlain unconformably by beds of the Paleocene or Eocene.

Distribution.—The Colón formation is distributed widely throughout western Venezuela and eastern Colombia. Its outcrop belt extends along the entire northwestern flank of the Mérida Andes and eastern front of the Perijá Range. It has been encountered on the north side of Toas Island and in a number of wells drilled in northwestern Zulia, and is believed to underlie the entire Maracaibo basin.

Age and paleontology.—The age of the Colón formation in the Barco Concession has been definitely established by Cushman and Hedberg (1941, pp. 79–100) as Upper Cretaceous (Campanian-lower Maestrichtian). Although the formation is generally barren of megafossils, it contains a prolific microfauna, which these authors have described in detail and have employed to divide it into a lower or *Pullenia cretacea* zone, 1,000 feet thick and Taylor (Campanian) in age, and an upper or *Siphogenerinoides bramlettei* zone, 500 feet thick and lower Maestrichtian in age.

The following have been identified by H. Borger (unpublished report) from collections made by P. P. Wolcott.

Río Escalante, northern Táchira. From shale 20 meters above base of formation.
Nodosaria sp.
Robulus spp.
Bulimina spp.
Dentalina cf. *wimani* Brotzen—Upper Cretaceous, Sweden; Colón, Colombia and Venezuela
Pseudogaudryinella colombiana Cushman and Hedberg—Colón Shale, Lower zone
Dentalina cf. *lorneiana* d'Orbigny—Ripley, U.S., Colón, Colombia
Ventilabrella carseyae Plummer—Navarro, Arkadelphia, U. S.
Bolivinoides rhomboidea (Cushman)—Mendez, Mexico
Gümbelina spp. (Cretaceous forms)
Planulina spissocostata Cushman—Taylor, Lower Navarro, U. S., Colón, Colombia
Globotruncana fornicata Plummer—Navarro, Upper Taylor, U. S., Colón, Colombia and Venezuela
Río Omuquena, north-central Táchira. From shale 510 meters below top of formation.

Robulus münsteri (Roemer)—Taylor, U. S., Colón, Colombia and Venezuela
Siphogenerinoides sp. cf. *S. cretacea* Cushman—Colón, Colombia
Marginulina bullata Reuss—Upper Cretaceous, Luschitz, Bohemia; Taylor and Navarro, U. S.; Colón shale, Venezuela
Gyroidina depressa (Alth) var. *colombiana* Cushman and Hedberg—Lower zone, Colón, Venezuela
Gaudryina cf. *laevigata* Franke
Gyroidina globosa (Hagenow)—Kreide, Rügen, Germany; Navarro, Taylor, Austin, U. S.; Cretaceous, Trinidad and Mexico, Lower zone, Colón, Colombia
Gümbelina spp.
Lagena sp.
Pullenia cretacea Cushman—Navarro and Taylor, U. S.; Lower zone, Colón, Colombia and Venezuela
Globigerina spp.
Globotruncana sp.
Bulimina sp.
Valvulineria allomorphinoides (Reuss)—Kreide formation, Germany; Taylor, U.S.; Mendez, Mexico; Cretaceous, Trinidad; Colón, Venezuela and Colombia
Chilostomella sp.
Loxostoma sp.
Ostracoda

Río de Oro, northern Táchira. From shale 230 meters above base of formation.
Dorothia bulletta (Carsey)—Navarro and Taylor, U. S.; Colón, Colombia and Venezuela
Planulina spissocostata Cushman—Navarro and Taylor, U. S., Colón, Colombia and Venezuela
Globotruncana fornicata Plummer—Navarro and Taylor, U. S.; Colón, Colombia and Venezuela
Gaudryina cf. *G. laevigata* Franke—Taylor, U. S.; Colón, Colombia and Venezuela
Pseudogaudryinella colombiana Cushman and Hedberg—Lower zone, Colón, Colombia and Venezuela
Gümbelina spp.
Palmula rugosa (d'Orbigny) var. *projecta* (Carsey)—Taylor, U. S.; Colón, Colombia and Venezuela
Siphogenerinoides cretacea Cushman—Colón, Colombia and Venezuela
Saracenaria triangularis (d'Orbigny)—Upper Cretaceous, Paris basin; Navarro to Austin, U. S.; Colón, Colombia and Venezuela.
Planoglobulina taylorana Cushman—Taylor, U. S.; Colón, Venezuela and Colombia
Bulimina petroleana Cushman and Hedberg—Colón, Colombia and Venezuela
Globigerina cretacea d'Orbigny—Craie blanche, France; Upper Cretaceous, Colombia and Venezuela
Massilina texasensis Cushman—Upper zone, Colón, Colombia and Venezuela; Navarro, U. S.
Dantalina cf. *D. consobrina* (d'Orbigny) Cretaceous, Trinidad; Ripley, U. S.; Colón, Colombia and Venezuela
Ellipsonodosaria sp.
Anomalina spp.
Valvulineria cf. *V. allomorphinoides* (Reuss)

Correlation.—The Colón formation is probably the equivalent of the Churcurri shales of Colombia and the upper part of Liddle's (1928, pp. 154–61) Guayuta formation of eastern Venezuela, now known as the San Antonio formation of the Guayuta group (Hedberg, 1937, pp. 242–43).

MITO JUAN FORMATION (UPPER CRETACEOUS)

The name Mito Juan formation is derived from the Quebrada Mito Juan, a tributary of the Río Sardinata, on the north dome of the Petrolea oil field of the Barco Concession in Colombia, and is used by Garner (1926, p. 679) and by Hedberg and Sass (1937, pp. 83–84) to designate a predominantly shale formation that is exposed along this stream.

Lithology.—The formation is brackish water to marine in origin and is composed principally of massive, black, gray or greenish gray shales that are locally sandy. These shales are more prominent in the lower part of the formation and in many places are difficult to recognize, lithologically, from the underlying Colón shales. The shales of the upper part of the Mito Juan locally contain

interbedded limestones varying from a few centimeters to 75 centimeters in thickness, and sandstones, generally thinly bedded but in some places attaining a thickness of one meter. The limestones are gray, sandy and generally glauconitic. Elongate concretions of limestone and ironstone are common. The sandstones are light gray to greenish gray in color, generally fine-grained but in places gritty, calcareous, glauconitic, and carbonaceous. The sandy part of the Mito Juan exhibits a simple tourmaline-zircon mineral suite and many of the limestones contain orange opaques.

Thickness.—The maximum development of the Mito Juan formation occurs in the southern part of the basin. In the State of Táchira the thickness varies from 215 meters (706 feet) to 755 meters (2,480 feet), and in the Barco area of Colombia, Notestein, Hubman, and Bowler (1944, p. 1185) report thicknesses ranging from 275 meters (903 feet) to 420 meters (1,378 feet). In the northern part of the basin a thickness of 153 meters (501 feet) has been reported for the section penetrated by the recent DM-2 well in the District of Mara, Zulia, west of Lake Maracaibo.

Stratigraphic relationship.—The Mito Juan formation of this paper includes both the Mito Juan and the Río de Oro formations of Hedberg and Sass (1937, pp. 85–87). In this, the procedure of Notestein *et al.* (*op. cit.*) has been followed. In view of the fact that the glauconitic limestones and sandstones of the upper part of the formation pinch out toward the south in the Barco region, the latter authors prefer to treat them as a local facies rather than as a separate formation. However, this lithologic differentiation of the Mito Juan does have stratigraphic value in some areas and the present writer prefers to consider the Río de Oro beds as locally the upper member of the Mito Juan formation.

The Mito Juan conformably rests on the Colón shale and the contact can be drawn sharply on the basis of the distinct foraminiferal faunas. The top of the Río de Oro glauconitic limestone member marks the top of the Mito Juan formation and the contact appears to be conformable with the overlying Catatumbo formation.

Distribution.—The Mito Juan formation is ordinarily difficult to differentiate from the subjacent Colón formation in the field, and the two have usually been mapped together either as Colón alone or as Colón-Mito Juan. The Río de Oro member is known to extend northward from the Barco Concession to the Quebrada El Mene, a southern tributary of the Río Negro in the District of Perijá in western Zulia, where it disappears beneath the overlapping Upper Eocene La Sierra formation. On the north in the Sierra de Perijá no attempt has been made to differentiate between the Colón and Mito Juan, although a paleontological separation is probably possible. The Mito Juan has been determined paleontologically in the DM-2 well of the District of Mara and on the north shore of Toas Island. It has been mapped along the northwest flank of the Mérida Andes as far northeast as the Río Chama in west-central Mérida but has not been found in Trujillo.

Age and paleontology.—The Mito Juan formation is of definite Upper Cre-

taceous (upper Maestrichtian) age. Hedberg and Sass (1937, p. 86) note the discovery of the ammonites *Sphenodiscus* and *Coahuilites*, identified by Spath, in the base of the Río de Oro member in the Barco Concession. Maestrichtian Foraminifera were described by Cushman and Hedberg (1941) from the Mito Juan shales of the same region. The Foraminifera of the Mito Juan indicate a brackish-water to shallow-marine deposition in a sheltered sea, while those of the underlying Colón shales include a large pelagic element (species of *Globigerina*, *Globotruncana*, and *Gümbelina*) and prove the presence of deeper marine conditions in an open sea.

Fossils collected from the Mito Juan on the Río Lobaterita in western Táchira have been identified by Olsson as follows.

Trigonarca sp.
Roudairea cf. *auressensis* Coquand
Antigona sp.
Sphenodiscus sp.
Parapachydiscus sp.

Borger identified the following typical microfauna from this formation in the Río Escalante of northern Táchira.

Ammobaculites sp.
Marginulina sp., cf. *M. ensis* (Reuss)
Gümbelitria cretacea Cushman
Cibicides coonensis (Berry)
Microgastropoda
Ostracoda

Dusenbury determined the following species of Foraminifera from the Mito Juan section in well DM-2 on the Los Tetones structure in the District of Mara, northwestern Zulia.

Ammomarginulina colombiana (Cushman and Hedberg)
Dorothia cf. *filiformis* (Berthelin), of Cushman and Hedberg
Astacolus santanderensis (Cushman and Hedberg)
Vaginulinopsis silicula (Plummer)
Nodosaria paupercula Reuss
Gümbelitria cretacea Cushman
Cibicides coonensis (Berry)

Correlation.—The Mito Juan formation is correlated with the lower part of the Umir formation in the valley of the Río Magdalena, Colombia, and with the lower or Upper Cretaceous part of the Santa Anita formation of Hedberg (1937, pp. 243–44) in the State of Anzoátegui in northeastern Venezuela.

CATATUMBO FORMATION (UPPER CRETACEOUS)

The Catatumbo formation is named after the Río Catatumbo, along which it crops out for some distance between Barranca Bermeja and Puerto Salado in the northern end of the Barco Concession. Notestein, Hubman, and Bowler (1944, pp. 1186–89) who first described this formation, state that the exposures along the river are unsatisfactory and therefore designate the section in Oro No. 3, a well located 10 kilometers northeast, as the type section.

Lithology.—The formation is composed of dark gray shales and clay shales, commonly carbonaceous and ferruginous, interbedded with gray to dark gray, micaceous, carbonaceous, fine-grained sandstone and argillaceous sandstone. It also includes a few beds of coal with a maximum thickness of one meter. The clay shales contain small nodules and thin lenses of brown clay-ironstone and more or less abundant siderite spherules, normally less than one millimeter in diameter.

Basally the lithologic character becomes transitional with that of the underlying Río de Oro member of the Mito Juan formation. The sandstones contain a garnet-chloritoid suite of heavy minerals.

Thickness.—Notestein *et al.* mention thicknesses ranging from 106 meters (348 feet) to 300 meters (984 feet) in and immediately south of the Barco Concession. The thinnest sections were measured on the Tibú and Sardinata anticlines, the thickest section on the Río Pamplonita near Donjuana south of the concession.

Stratigraphic relationship.—The base of the Catatumbo formation is conformable and transitional with the subjacent Río de Oro member of the Mito Juan formation. Notestein *et al.* say that the top of the formation is also apparently conformable with the basal sandstones of the Barco formation. However, since both the Catatumbo and Barco formations are stated to be thinner on the anticlines and thicker in the intervening synclines, there is good reason to suspect a certain amount of post-Cretaceous, pre-Eocene folding and erosion at the close of the deposition of the Catatumbo.

Distribution.—The known occurrences of the Catatumbo formation are confined to the vicinity of the Barco Concession in Colombia and to the contiguous portions of the states of Zulia and Táchira in Venezuela.

Age and paleontology.—The Catatumbo formation has been tentatively classified as Upper Cretaceous on the basis of the following fauna collected from arenaceous shale on the Río Catatumbo in the Puerto Salado area, identified by A. A. Olsson and listed in Notestein *et al.*

Ostrea sp.
Exogyra? sp., young specimens
Inoceramus? sp., shell prisms
Mytilus or *Modiolus* sp.
Venericardia sp.
Calyptraea sp.

Hedberg states that the fact that the *Ammomarginulina colombiana* zone extends upward from the Mito Juan into the lower part of the Catatumbo is further evidence of the Cretaceous age of the latter formation. Except for this one species, which indicates brackish-water conditions, the Catatumbo formation is generally barren of Foraminifera. Presumably the upper part of the formation is non-marine. From the fossil evidence available it is impossible to say whether the Catatumbo is uppermost Maestrichtian or Danian, but the former seems much more probable.

Correlation.—The Catatumbo formation is correlated directly with the lowest part of the "Third Coal horizon" of Liddle (1928, p. 181) in southwestern Zulia and northwestern Táchira and with the upper part of the Umir formation in the Magdalena valley in Colombia.

CENOZOIC

PALEOCENE

GUASARE FORMATION (UPPER PALEOCENE)

The name Guasare is derived from the Río Guasare, which forms the boundary between the districts of Paez and Mara in northwestern Zulia. The term "Río

Guasare formation" was introduced by Garner (1926, pp. 677–84) to define a formation of interbedded limestones, sandstones, and shales that crops out along the river. The name was later shortened to Guasare formation by Hedberg and Sass (1937, p. 87).

Lithology.—At the type section, only about 120 meters (394 feet) of the formation is exposed, but a complete section is visible on the Río Cachirí, 38 kilometers (24 miles) south. At both points the formation is composed largely of well stratified, tan to gray, hard, fossiliferous, glauconitic limestone and sandy limestone in beds up to 4 feet thick. Seams of closely packed oyster remains are common. The presence of abundant *Venericardia* has led some to refer to the formation as the "*Venericardia* limestone." Interstratified with the limestones, but in subordinate amounts, are beds of calcareous, glauconitic sandstone, quartzitic sandstone, and gray, calcareous shale.

Heavy minerals present in the formation are: garnet, tourmaline, zircon, hematite, ilmenite, leucoxene, pyrite, magnetite, barite, muscovite, chloritoid, and rutile.

The type of sedimentation is shallow marine.

Thickness.—On the Río Cachirí the Guasare formation has a thickness of 390 meters (1,280 feet). About 45 kilometers (28 miles) east, along the 25-kilometer La Paz-Netick-Tetones structural trend, the maximum recorded thicknesses in wells are: La Paz field, 366 meters (1,200 feet); Netick field, 326 meters (1,070 feet); and exploratory well DM-1 on the Kilometer-24 structure, at least 427 meters (1,400 feet). About 250 kilometers (155 miles) southeastward across the basin, in the Carache River valley in northeastern Trujillo, the formation has a maximum thickness of 350 meters (1,150 feet). These measurements indicate a rather uniform thickness for the formation within the limits of its known distribution.

Stratigraphic relationship.—Throughout its area of occurrence, the Guasare formation is everywhere underlain by the Mito Juan or by the Colón. A disconformity is present at this contact as evidenced by the absence of uppermost Cretaceous and Lower Paleocene sediments.

Where it is exposed in the foothills of the Sierra de Perijá in northwestern Zulia, the Guasare is conformable with the overlying Marcelina formation. The age of the latter is not known exactly but is probably Lower and Middle Eocene. In the Netick, La Paz, and Tetones oil fields, about 45 kilometers (28 miles) to the east, a disconformity is present between the Guasare and the overlying Upper Eocene Potreritos formation. Across the basin, along the Río Misoa in eastern Zulia, the Guasare is conformable with the overlying Trujillo formation of the Lower and Middle Eocene.

Distribution.—The known occurrences of the Guasare formation are confined to a belt 50 to 60 kilometers (31 to 37 miles) in width which extends from the area of the type exposure in the foothills of the Sierra de Perijá in northwestern Zulia, southeastward across the basin through eastern Zulia and Trujillo. It

crops out in the overturned section on the north shore of Toas Island and is present in the wells of the La Paz, Netick, and Tetones (Mara) oil fields. On the eastern side of the basin it is partially exposed in the headwaters of the Río Misoa in eastern Zulia and is well exposed in the Río Carache valley in the northeastern part of the State of Trujillo.

Age and paleontology.—The Guasare formation has been assigned to the Upper Paleocene (Thanetian of Europe, upper Midway of the Gulf Coast of the United States) on the basis of its molluscan and foraminiferal fauna. Rutsch (1936) examined specimens of *Venericardia* from the outcrops on the Río Guasare, Río Cachirí and Toas Island. Due to the poor preservation of the material, he was not able to make a definite specific determination, but considered the specimens in part probably identical with specimens from the Paleocene of Soldado Rock at the southern entrance to the Gulf of Paria and of Marac Quarry in southern Trinidad, which he tentatively identified as *Venericardia parinensis* Olsson, a species described from the Middle Eocene Parinas formation of Perú. However, Olsson states that, although he considers the Guasare specimens to belong to the same species as the Soldado Rock and Marac Quarry specimens, all of these are quite different from *V. parinensis* and belong to a new species, described in an appendix to this paper as *Venericardia* (*Venericor*) *toasensis* Dusenbury n. sp. Hedberg and Sass mention that *Turritella negritosensis* Woods, described from the Negritos formation of Perú, and *Ostrea sellaeformis* Conrad, ranging through the Lower and Middle Eocene of the United States, have been tentatively identified from the Guasare. The laboratory of the Caribbean Petroleum Company has on display an excellent specimen, collected from the type section of the Guasare formation, of *Peruluta crassiuscula* (Woods), another species originally described (as *Volutospina*) from the Negritos formation. J. W. Durham collected a nautiloid from the Guasare on Toas Island and has tentatively identified it as *Cimomia* sp. aff. *C. vincenti* Miller, described from the Paleocene Landana beds of Kabinda, Portuguese West Africa.

The larger Foraminifera have not as yet been found in northwestern Zulia but are quite abundant in eastern Zulia and Trujillo. In the Río Carache valley of northeastern Trujillo between Casa de Zinc and La Cuchilla the Guasare limestones contain *Venericardia* near the base and, higher, reefs of *Lithothamnium*, with which the following Upper Paleocene larger Foraminifera occur.

Ranikothalia antillea (Hanzawa)
Ranikothalia soldadensis (Vaughan and Cole)
Discocyclina azuerreverei Caudri
Lepidorbitoides cf. *planasi* Rutten of Caudri

This same fauna in a poorer state of preservation was found in the Guasare on the Río Misoa in the vicinity of El Baño, eastern Zulia. It is correlated with the Paleocene fauna described by Caudri (1944) from limestones near San Juan de los Morros, State of Guárico, central Venezuela, and this in turn is correlated with the Paleocene fauna described by Vaughan and Cole (1941) from the Soldado formation of Soldado Rock.

The following mixed fauna of smaller Foraminifera and macrofossils was identified by Dusenbury from the Guasare on Toas Island.

Haplophragmoides sp.
Astacolus crepidula (Fichtel and Moll), Jurassic to Recent
Bulimina sp.
Eponides lotus (Schwager), Paleocene and Lower Eocene
Anomalina scrobiculata Schwager, Upper Paleocene and Lower Eocene
Cibicides praecursorius (Schwager), Upper Paleocene and Lower Eocene
Nuculana? sp.
Ostrea buski Woods, Negritos formation of Perú
Venericardia (*Venericor*) *toasensis* Dusenbury n. sp.
Pitar? sp.
Turritella sp.
Decapod crustacean fragments

In the exploratory well DM-1, drilled by the Caribbean Petroleum Company in the District of Mara, Zulia, 1,400 feet of the Guasare formation was penetrated and an abundant microfauna was recovered from the core and ditch samples. These were thoroughly studied by Dusenbury and the following species are among those listed by him.

Eponides lotus (Schwager), Paleocene and Lower Eocene
Nodosaria latejugata Gümbel. Paleocene to Middle Eocene
Discorbis midwayensis var. *soldadoensis* Cushman and Renz, Upper Paleocene
Globigerina pseudobulloides? Plummer, Paleocene to Middle Eocene
Cibicides howelli Toulmin, Upper Paleocene and Lower Eocene
Astacolus toddae (Cushman), Paleocene and Lower Eocene
Lenticulina degolyeri (Plummer), Paleocene and Lower Eocene
Cibicides praecursorius (Schwager), Upper Paleocene and Lower Eocene
Robulus sp. Cushman and Renz, Upper Paleocene (Soldado formation)
Spiroplectammina laevis var. *cretosa* Cushman, Upper Cretaceous (Campanian) to Upper Paleocene of Alabama (Naheola formation)
Vaginulinopsis wilcoxensis Cushman and Ponton, Upper Paleocene and Lower Eocene
Cibicides williamsoni Garret, Upper Paleocene and Lower Eocene
Dorothia alabamensis Cushman, Lower Paleocene of Alabama (Sucarnoochee formation)
Ammobaculites midwayensis Cushman, Lower Paleocene
Coleites reticulosus (Plummer), Upper Paleocene and Lower Eocene
Dentalina eocenica? Cushman, Upper Paleocene

Correlation.—The large fossils of the Guasare correlate the formation with the Paleocene Soldado formation of Soldado Rock and Marac Quarry, Trinidad, and with at least part of the Negritos formation of northwest Perú. The larger Foraminifera correlate the Guasare with the Paleocene limestones of San Juan de los Morros and the Soldado formation of Soldado Rock. The smaller Foraminifera correlate the Guasare with the Soldado formation of Soldado Rock (Cushman and Renz, 1942) and with the Wills Point and Naheola formations of the upper part of the Midway group of the United States Gulf Coast. Limestones equivalent to the Guasare and containing *Venericardia* are well developed in the upper valley of the Río Ranchería between Fonseca and Arroyo Cerrejón, Department of Magdalena, northeastern Colombia. They are known as the Arroyo Cerrejón limestone, according to Liddle (1943, p. 37).

EOCENE

Eocene rocks are distributed widely throughout western Venezuela and east-

ern Colombia and in the Maracaibo basin are found in almost continuous outcrop along the foothills of the bordering mountains. It is believed that the entire Eocene sequence is represented in the basin, although the sediments referred to as Lower Eocene are non-fossiliferous and the age assignment is based entirely on position in the section. The presence of the Middle Eocene has been firmly established on paleontologic evidence. The widespread deposits of the Upper Eocene with their abundant faunas have been known for many years.

TRUJILLO FORMATION (LOWER TO MIDDLE EOCENE)

The term Misoa-Trujillo formation, referred to by Hodson (1926, p. 4) and Liddle (1928, p. 181), was used originally to designate a thick shale and sandstone section which crops out extensively in the Serranía de Trujillo and a spur of this range, the Cerro Misoa. These ranges have a northerly trend through the eastern part of the State of Zulia, east of Lake Maracaibo. The parent range extends southward through the State of Trujillo. In the present paper the hyphenated term has been separated, and the names Trujillo and Misoa have been assigned to the two distinct unconformable lithologic units which constitute the sequence.

The type exposure of the Trujillo formation is along the Río Misoa, where this stream cuts the western flank of the Serranía de Trujillo and forms the boundary between the districts of Sucre and Bolívar in eastern Zulia.

At its base the formation is in contact with the Guasare formation near the crest of the El Baño anticline. It extends downstream from this point for a distance of approximately 23 kilometers (14 miles) to its contact with the overlying Misoa formation, which forms a prominent strike ridge along the western flank of the Serranía de Trujillo.

Lithology.—The Trujillo formation is composed largely of dark blue-gray to dark gray and black, locally micaceous and carbonaceous shale, with subordinate amounts of gray and brown sandstone. The basal part of the formation exhibits marked induration, almost to the point of metamorphism, and innumerable white quartz veins cut the shale and sandstone members at right angles to the bedding. These veins vary in width from less than one inch to 12 inches, and are believed to represent secondary deposition along fractures by ascending mineral waters. Continuing upward in the section, the quartz veins become progressively less in number and in the upper part are scarcely present. At the same time the shales become less hard, lose their slaty character and are generally soft and fissile. Occasionally present are ellipsoidal and discoidal, pyritic, sandy limestone concretions that weather to ironstone. Thin seams of sub-bituminous coal have been noted in the lower part of the formation.

The sandstones, which are more pronounced in the upper half of the formation, are gray and brown, fine- to medium-grained, micaceous, and locally carbonaceous. They are generally well stratified and vary in thickness from a few centimeters to 2 meters.

Thickness.—The thickness of the formation in the type section has been estimated at 4,876 meters (16,000 feet). This may be excessive in view of probable repetition by faulting and sharp folding in the shale.

Stratigraphic relationship.—On the Río Misoa the contact with the underlying Guasare formation is not clearly defined but is believed to be conformable.

The Trujillo is unconformable above with the Misoa formation. In the Carache River valley of northeastern Trujillo there is evidence of angular discordance along this contact.

Distribution.—The present known outcrop occurrence of the Trujillo formation extends from the Zulia-Lara-Falcón state boundary junction to the Carache River valley in the northeastern part of the State of Trujillo.

Age and paleontology.—On the basis of its stratigraphic position and faunal content the Trujillo formation has been assigned to the Lower and Middle Eocene. There is definite proof of a Middle Eocene age for its upper half and it is probable that the thick, unfossiliferous lower portion may extend into the Lower Eocene.

Megafossils and microfossils are exceedingly rare. From samples collected on the Río Misoa near the middle and top of the formation, the following Foraminifera, indicative of the Middle Eocene have been listed by Dusenbury.

Middle part of the formation
- *Cyclammina pusilla* Brady
- *Plectina* cf. *dalmatina* (Schubert)
- *Robulus kemperi* (Hanna)
- *Gyroidina guayabalensis* Cole
- *Cibicides venezuelanus* Nuttall
- *Cibicides* sp.
- *Globigerina* sp.

Upper part of formation
- *Ammobaculites* sp.
- *Globigerina bulloides* d'Orbigny
- *Textularia* sp.
- *Gyroidina guayabalensis* Cole
- *Cornuspira?* sp.
- *Cibicides* sp.
- *Tritaxilina pupa* (Gümbel)
- *Globobulimina?* sp.
- Microgastropoda
- Ostracoda

A number of Middle Eocene species have been obtained from the Carache River valley of central Trujillo. The collection was taken from a thin layer of coarse sandstone and fine conglomerate interbedded in highly dipping black shale along the north side of the road between Puente Gomez and Casa de Zinc and about 700 meters west of the junction with the Chejendé road. The first two of the following identifications were made by Dusenbury and the remainder by Olsson.

- *Potamides* (*Telescopium*) sp.
- *Turritella* cf. *wechesensis* Bowles
- *Perucerithium* cf. *restinensis* Olsson
- *Pseudoglauconia* cf. *lissoni* Douvillé of Woods in Bosworth
- *Levifusus?* sp.
- *Pitar?* sp.

Correlation.—Liddle (1928, pp. 181–98) includes the Trujillo formation in his his "Third Coal horizon" along with the Angostura, Catatumbo, Barco, Tabla, Los Cuervos, Guasare, and Marcelina formations. G. E. Tash (1937, p. 168) includes the Trujillo and the "second orbitoid horizon" in his lower Misoa-Trujillo member. However, the orbitoids of the "second orbitoid horizon" are

of Upper Eocene age and, in the Río Carache section, occur between the unconformity at the top of the Trujillo and the base of the lowermost massive quartzites of the Misoa formation.

The Trujillo is believed to be a deeper-water, partly marine equivalent of the Marcelina formation in the northern Sierra de Perijá and the Angostura formation in the states of Táchira, Mérida, and southwestern Trujillo. It can also be correlated with the combined Barco and Los Cuervos formations of the Barco Concession (Notestein, Hubman, and Bowler, 1944, pp. 1190–94) and with a part of the San Juan de los Morros Eocene section in the State of Guárico, from which Olsson has collected a few Middle Eocene fossils.

ANGOSTURA FORMATION (LOWER TO MIDDLE EOCENE)

The name Angostura formation is derived from the Angostura Bridge, which crosses the Río Lobaterita on the road from La Cortada to Colón in the western part of the State of Táchira. The term is introduced here for the first time to designate a coal-bearing formation which crops out at this locality. The base of the formation, where it is in contact with the Catatumbo, is a short distance downstream from the bridge. Its upper contact, with the prominent Misoa (Mirador) formation, is about 600 meters (1,969 feet) upstream from the bridge.

The coal measures of this area were referred to originally by Liddle (1928, p. 181) and Kehrer (1937, p. 48) as the "Third Coal horizon." The name is not valid since, in its original application, it embraces formations belonging to both the Eocene and Cretaceous and, furthermore, is non-geographic in origin.

Lithology.—Throughout the states of Mérida and Táchira the formation is composed mainly of interbedded sandstone and shale with a few beds of coal. The sandstones are well bedded, laminated, and cross-laminated, gray to dark greenish gray, fine-grained, locally carbonaceous and plant fossiliferous. The shales are gray to black, hard, arenaceous, and locally sandy, carbonaceous, and plant fossiliferous. Small ironstone concretions are locally embedded in the shale. The coal beds, of which there are several, are interbedded with the sandstone and shale. They are sub-bituminous to bituminous, commonly shaly, and vary in thickness from a few centimeters to one meter.

The formation contains a complex suite of titanium minerals as well as opaques, but lacks the brookite and anatase which are characteristic of the sandstone in the overlying Misoa (Mirador) formation.

In southwestern Trujillo the formation is essentially the same as in Táchira and Mérida but is much thinner, and the coal beds are less well developed.

The formation is lagunal and was deposited in fresh to brackish water.

Thickness.—At the type locality the Angostura formation is about 400 meters (1,312 feet) thick but thins northward to 200 meters (656 feet) on the Río de Oro in northern Táchira and 75 meters (246 feet) on the Río Buena Vista in southwestern Trujillo.

Stratigraphic relationship.—In Táchira and Mérida the formation is discon-

formable with the underlying Mito Juan. In southwestern Trujillo, the Mito Juan is missing and the Angostura is unconformable with the underlying Colón formation.

An unconformable relationship is believed to exist between the Angostura and overlying Misoa (Mirador) formation.

Distribution.—The formation is present as a recognizable unit throughout the states of Táchira and Mérida and northward to the village of Escuque in the southwestern part of the State of Trujillo. It appears to wedge out beyond this point.

Age and paleontology.—On the basis of its position in the section and suggested correlation with the Trujillo formation, the Angostura formation is considered to be Middle and Lower Eocene in age. Macrofossils have never been found and foraminifera are extremely rare. Those reported consist mainly of brackish water species of the arenaceous genera *Ammobaculites*, *Trochammina*, and *Reophax*.

Correlation.—The Angostura is the equivalent of the Marcelina formation and is probably a fresh- to brackish-water facies of the Trujillo formation. It can be correlated with the Eocene portion of the "Third Coal horizon" of the District of Colón, Zulia, and the combined Barco and Los Cuervos formations of the Barco Concession of eastern Colombia.

MARCELINA FORMATION (LOWER TO MIDDLE EOCENE)

The term Marcelina is introduced at this time to designate a coal-bearing formation which crops out along the Caño Marcelina, a tributary of the Río Guasare in the southwestern part of the District of Paez, Zulia. On the Río Guasare the base of the Marcelina is marked by the top of the highest limestone bed of the Guasare formation about 550 meters downstream from the junction with Caño Colorado, while the top is placed at the base of the coarse, massive Misoa sandstone section about 50 meters downstream from the junction with Caño Santa Rosa.

Lithology.—The Marcelina is a fresh- to brackish-water formation and at the type locality is composed largely of interbedded sandstones, shales, sandy shales, and coal beds. In the lower part of the formation the sandstones are generally light gray, locally calcareous, massive, and thickly bedded. Higher in the formation they are thinly bedded and interlaminated with gray shale, and exhibit micaceous and carbonaceous bedding planes. The shales, which are generally covered, comprise about 25 per cent of the formation and are dark gray to black, conchoidal to pencil fracturing. Several zones in the sandstone and shale members contain large blue-gray sandstone and sandy limestone nodules. These are elongate and reach as much as 4 to 8 feet in length and 2 to 4 feet in diameter.

Numerous beds of sub-bituminous to bituminous coal are present and their best development occurs in the lower part of the formation. As a rule, they vary in thickness from a few centimeters to 3 meters (10 feet) but at one point a bed about 10 meters (33 feet) is present. At El Carbón on the Río Guasare and be-

tween Las Playitas and El Toro on the north shore of Toas Island the coal has been mined commercially, but sustained production is not maintained.

Hedberg and Sass (1937, p. 91) report a limited heavy-mineral separate from the sandstones of the formation. They list ilmenite, leucoxene, zircon, tourmaline, and rutile. On Toas Island Mas Vall finds epidote, muscovite, tourmaline, zircon, hematite, and magnetite.

On the Río Guasare and its tributaries, Caño El Paso del Diablo and Caño Marcelina, are exposures up to 4 meters (13 feet) thick of baked, red- and blue-tinted shale that, in places, has an almost glassy texture. They are believed to be the result of fusing by oxidation of the associated coal. They have been mistaken by some for basalt dikes.

Thickness.—The thickness of the Marcelina formation in the type section is about 610 meters (2,000 feet). On the nearby Río Socuy the thickness has almost doubled but there are indications here of repetition by faulting. On Toas Island most of the formation has been cut out by faulting.

Stratigraphic relationship.—In the type area the Marcelina is conformable with the underlying Guasare formation. It is overlain disconformably by the Misoa formation.

Distribution.—The outcrop area of the Marcelina formation is chiefly in the eastern foothills of the northern Sierra de Perijá, where it occupies a narrow belt extending from the type area southward to the Río Palmar, a distance of about 60 kilometers (37 miles). It probably underlies the Manuelote syncline adjacent to the mountain front but has not been encountered and was probably never deposited over the shallow basement area east of the Los Ocho fault. On the east it appears again on the north coast of Toas Island, where it is overthrust by limestone of the Apón formation.

Age and paleontology.—On the basis of its position in the section and suggested correlation with the Trujillo formation, the Marcelina formation is believed to be Middle and Lower Eocene in age. The rare brackish-water fossils which have been found are poorly preserved and have no stratigraphic value.

Correlation.—The Marcelina formation is equivalent to the La Rosa coal measures of Garner (1926, p. 680), but this latter name must be rejected in order to prevent confusion with the Miocene petroliferous La Rosa formation of the Bolívar Coastal oil field. The name La Rosa is evidently an error for Santa Rosa, as the type section is along the Caño Santa Rosa, another tributary of the Río Guasare lying east of the Caño Marcelina.

The Paso Diablo formation, described by Hedberg and Sass (1937, pp. 90–91), includes both the Marcelina and Misoa formations of the present paper and possibly the Potreritos also, to judge by analysis of the heavy minerals. Its type section is along the Caño El Paso del Diablo, a third tributary of the Río Guasare, in the northwestern part of the District of Mara.

The nearest correlative of the isolated Marcelina exposures is the Eocene portion of the "Third Coal horizon" of the District of Colón, Zulia. Others are

the combined Barco and Los Cuervos formations of the Barco Concession in Colombia, and the Angostura formation of Táchira, Mérida, and southwest Trujillo. It is probably a fresh- to brackish-water facies of the Trujillo formation of northwest Trujillo and eastern Zulia.

BARCO FORMATION (LOWER EOCENE)

The Barco formation of Notestein, Hubman, and Bowler (1944, pp. 1190–92) is named after the East Barco Ridge, a prominent escarpment formed by resistant sandstones of this formation along the east flank of the Petrolea anticline in the southeast corner of the Barco Concession in Colombia. It consists of interbedded sandstones, shales and clay shales with the sandstones predominant and forming half to two thirds of the total thickness. The sandstones are commonly argillaceous, cross-bedded, micaceous, carbonaceous, or petroliferous. The shales are in many places silty, micaceous, and carbonaceous and locally rich in siderite spherules. The average thickness on the Concession is 194 meters (636 feet), but the thickness is greater in the synclines than on the anticlines. This suggests post-Cretaceous, pre-Eocene folding and erosion with an unconformable relationship between the Barco and underlying Catatumbo. The contact between the Barco and the overlying Los Cuervos formation appears to be conformable.

The Barco formation is unfossiliferous and largely non-marine. It is correlated directly with the Tabla sand (Liddle, 1928, pp. 190–93) of the "Third Coal horizon" in the District of Colón and the southern part of the District of Perijá, Zulia. The name is taken from the Tabla parcel on the Río Tarra anticline in the southwest part of the District of Colón.

The District of Colón in southwestern Zulia is the type area for the "Third Coal horizon" of Liddle (1928, p. 181). As already mentioned, this name is non-geographic in origin and refers to beds of Upper Cretaceous to probable Middle Eocene age; hence, it should be discarded. In attempting to answer the first of these two objections, Hedberg substituted the manuscript name Orocué formation, later mentioned in a publication by Cushman and Hedberg (1941, pp. 79–81), and finally changed to Orocué group by Notestein, Hubman, and Bowler (1944, p. 1186). The type locality is presumably in the vicinity of the village of Orocué, west of the Barco Concession in the Department of Santander del Norte, Colombia. However, the second objection is still valid, and since it is not good practice to have a group astraddle the Cretaceous Eocene unconformity, the writer recommends the discarding of the name Orocué entirely. It is further recommended that W. S. Olson's terminology in present use on the Barco Concession be extended into Colón and southern Perijá. Thus, the part of the "Third Coal horizon" below the Tabla sand would be assigned to the Catatumbo formation, the Tabla sand would be renamed the Barco formation, and the part of the "Third Coal horizon" above the Tabla sand would become the Los Cuervos formation.

The Lora coal measures of Garner (1926, p. 680), named for the Río Lora in

the southern part of the District of Perijá, Zulia, is another unsuitable term for the section generally known as the "Third Coal horizon."

LOS CUERVOS FORMATION (MIDDLE EOCENE)

The type section of the Los Cuervos formation of Notestein, Hubman, and Bowler (1944, pp. 1192–94) is situated on the Quebrada Los Cuervos, a tributary of the Río Catatumbo above Puerto Barco, in the northern part of the Barco Concession, Colombia. The formation is composed mainly of shales and clay shales with some interbedded sandstones, and ranges in thickness from 345 meters (804 feet) to 490 meters (1,607 feet) on the Concession. The lower 75 meters (246 feet) consists of dark gray, carbonaceous shales and micaceous, carbonaceous fine-grained sandstones, intercalated with bituminous coal beds with a maximum thickness of 2.5 meters (8.2 feet) and an average thickness of 0.5 to 1 meter. Above these coal measures the shales and clay shales are in places mottled and commonly contain spherulitic siderite. The base of the Los Cuervos is conformable with the Barco, but the top is at least locally unconformable with the Mirador formation.

The Los Cuervos is principally non-marine in origin, but a thin black shale close to the base of the formation in the Puerto Salado area was found to contain the following marine to slightly brackish-water fauna identified by Olsson.

Ostrea sp.
Anomia? sp.
Diplodonta? sp.

Unfortunately, this fauna is inadequate for the determination of the age of the Los Cuervos.

The Los Cuervos is the exact equivalent of the part of the "Third Coal horizon" above the Tabla sand in the District of Colón, southwestern Zulia. The combined Los Cuervos and Barco formations are considered to be correlative with the Angostura, Marcelina, and Trujillo formations.

MISOA FORMATION (UPPER EOCENE)

The name Misoa is used to designate the thick, essentially sandstone, deposits which constitute the Upper Eocene part of the original Misoa-Trujillo formation. The type area of the Misoa formation is the Cerro Misoa east of Lake Maracaibo in the District of Sucre, Zulia. The best exposures are along the Río Misoa, where this stream cuts through the western flank of the Serranía de Trujillo along the Sucre-Bolivar district boundary in eastern Zulia.

Lithology.—The origin of the Misoa formation is due to deposition in nearshore to lagunal waters. The Río Misoa section is composed mainly of hard, quartzitic, light gray to brownish gray, medium to coarse-grained, locally conglomeratic, thick-bedded to massive, sandstone. In the lower part of the formation are subordinate amounts of fine to medium, gray and dark gray, carbonaceous, micaceous, laminated and cross-laminated sandstone. Flagstone structure and ripple

marking are common. Bedding planes are commonly defined by microscopically thin carbonaceous laminae.

Interbedded with the sandstones are gray to dark gray shales that probably comprise about 15 per cent of the formation. They are generally thin-bedded, sand-laminated, highly carbonaceous, and commonly micaceous. They vary from a few inches to several feet in thickness.

Locally, the base of the formation consists of orbitoidal limestone, sandy limestone and calcareous sandstone. These beds are known as the Cuicas limestone member of the Misoa. They crop out along the upper part of the side road to the town of Cuicas in northeastern Trujillo, as well as along the main Carache valley road.

The formation contains a simple suite of heavy minerals, notably tourmaline, zircon, and rutile. Zones of brookite and anatase are common.

Thickness.—At the type section, the Misoa formation is 1,725 meters (5,658 feet) thick. This is the maximum that has been recorded in the basin. The formation thins in a short distance southward and varies from about 365 meters (1,197 feet) in southwestern Trujillo to an average of 110 meters (374 feet) in the Táchira-Mérida region. In the Barco Concession area of Colombia the thickness of the equivalent Mirador formation varies from 160 to 400 meters (524 to 1,312 feet). In the foothills of the Sierra de Perijá in the western part of the Districts of Maracaibo and Mara, Zulia, the thickness varies from 122 to 183 meters (400 to 600 feet).

Stratigraphic relationship.—The Misoa formation initiated the Upper Eocene depositional cycle and is considered to be unconformable with the underlying Trujillo and equivalent formations. It is conformable and gradational above with the Paují and equivalent formations.

Distribution.—The Misoa formation is distributed widely throughout western Venezuela and eastern Colombia. It forms the Cerro Misoa, east of Lake Maracaibo, and the high flanking strike ridges of the Serranía de Trujillo. It flanks the Mérida Andes along the eastern and southern rim of the basin; and, as the Mirador, is present throughout the Barco Concession in eastern Colombia and extends northward from this area into Venezuela. It is present along the flanks of the Tarra and Río de Oro anticlines in the Colón District of Zulia and extends northward along the eastern front of the Perijá Range into the southern part of the District of Perijá, Zulia. In northern Perijá District it is overlapped by younger Eocene sediments. It reappears along the western limb of the Manuelote syncline and in step fault blocks along the eastern limb as far north as the Río Cachirí.

The Misoa formation probably underlies the entire Manuelote syncline in the western part of the Mara and Maracaibo districts of Zulia but it has not been encountered east of the Los Ocho fault. It is not present in the La Paz, Netick, and Tetones oil fields, nor has it ever been encountered in any of the exploratory wells in this general area, many of which entered older formations.

The presence of the younger Potreritos formation, which is without exception gradational with the Misoa where they are both present, suggests that this area remained above the deposition level during Misoa time.

The Misoa was encountered in Shell's deep test R-801 in the northern part of the Bolívar Coastal field of eastern Zulia and is productive on the Pueblo Viejo structure in the southern part of the District of Bolívar.

Age and paleontology.—The commonest fossil in the Misoa sandstones is the ramose *Halymenites*, which has been interpreted by some authorities as algal and by others as burrows of littoral animals. The fossil is locally so common along the northwest flank of the Andes that the name *Halymenites* sandstone has been applied to the Misoa there.

W. S. Hoffmeister (unpublished report) has identified the following genera from the outcrops along the Río Misoa.

Alectrion sp.
Arca sp.
Crassatellites? sp.
Nuculana sp.
Pecten sp.
Terebra sp.
Turritella sp.
Xanthopsis sp.

A collection was made by J. W. Nance from a black sandy shale zone, about 107 meters (350 feet) above the base of the formation, exposed along the road 150 meters east of Puente Gomez, which crosses the Río Carache in northeastern Trujillo. A. A. Olsson has identified the following.

Architectonica sullana Olsson
Architectonica sp.
Bursa sp.
Cardium sp., cf. *C. restinensis* Olsson
Cardium sp.
Cerithium sp.
Chama sp.
Corbula sp.
Hastula? sp.
Lyria sp.
Oliva sp.
Ostrea sp.
Pitar sp.
Protocardia sp.
Pyrula? sp.
Ectinochilus gaudichaudi alauda (Olsson)

The Misoa formation in the Bolívar Coastal fields is a brackish-water deposit in which the only known fossils are the arenaceous Foraminifera *Haplophragmoides* and *Ammobaculites*.

The Cuicas limestone member at the base of the Misoa in northeastern Trujillo contains the following Foraminifera identified by Dusenbury from thin sections.

Operculina sp.
Tubulogenerina sp.
Globigerina sp.
Rupertia sp.
Discocyclina sp.

The foregoing faunal lists determine the Upper Eocene age of the Misoa. In the easternmost part of the basin the formation is brackish water with thin marine intercalations, at the eastern lake shore it is entirely brackish water, and in the western part of the basin it becomes non-marine or was not deposited.

Correlation.—The Misoa formation of this paper includes the "second orbitoid level" (the equivalent of the Cuicas limestone member) at the top of the Lower Misoa-Trujillo of G. E. Tash (1937, pp. 167–72) and the massive quartzitic sandstones forming the lower part of his Upper Misoa-Trujillo. However, his Misoa-

Paují transitional beds, the shales of which contain a definite Paují microfauna, have been assigned to the Paují formation rather than to the Misoa. Northwestward this part of the section thickens, the Paují deep-water marine microfauna is gradually replaced by a less prolific, shallow marine to brackish-water microfauna, and lateral transition takes place between the lower Paují of the Mene Grande area of the District of Sucre and the Potreritos formation of the District of Bolívar.

The Bocorrón sandstone of Garner (1926, p. 680) in southwestern Trujillo is another Misoa equivalent, as is also the Corritos formation of Mackenzie (1937, pp. 262–63) on the southwest flank of the Mérida Andes in the State of Barinas. The Mirador sandstone was introduced into the published reports by Garner (1926, p. 680) and named from exposures on the Cerro Mirador of the Tarra anticline, District of Colón, southwestern Zulia. With the exception of several breaks due to faulting between the Río Buena Vista and the Río Mucujepe in Mérida, it has recently been traced around the south edge of the basin and into the type Misoa by Wolcott, thus confirming the correlation made by Liddle (1928, p. 181). Other correlatives are the La Paz sandstone of the Magdalena valley, Colombia; part of the upper half of the Paso Diablo formation of Hedberg and Sass (1937, pp. 90–91) in northwestern Zulia, and the Mojino quartzites of Halse (1937, pp. 180–81) in the southeastern part of the District of Buchivacoa, western Falcón.

The Misoa equivalent in northwestern Zulia has also been called the La Rosa sandstone by Garner (1926, p. 680), but this name, like his La Rosa coal measures, must be rejected to avoid confusion with the Lower Miocene La Rosa formation in the Bolívar Coastal oil field. As mentioned previously, the name La Rosa is an obvious error for Santa Rosa, the type section occurring on the north bank of the Río Guasare, just below the mouth of its tributary, the Caño Santa Rosa, in the southwestern part of the District of Paez, Zulia.

MIRADOR FORMATION (UPPER EOCENE)

The Mirador formation, often referred to as the "Mirador sandstone," derived its name from Cerro Mirador on the Tarra anticline in the Colón District of southwestern Zulia. Through wide usage, the name has become well established in the southern part of the Maracaibo basin. A number of early observers suggested a probable correlation of the Mirador and Misoa formations, but it is believed that this is the first time a direct field correlation has been reported.

PAUJÍ FORMATION (UPPER EOCENE)

The name Paují formation has been in use for a great many years to describe a predominantly shale formation that crops out along the flanks of the Serranía de Trujillo and Cerro Misoa in Trujillo and in the districts of Bolívar and Sucre, State of Zulia. Liddle (1928, p. 242) credits Arnold as being the first to apply the name. The type section is on the Río Paují in the District of Sucre, Zulia, where the stream emerges from the Serranía de Trujillo, about 20 kilometers (12 miles)

southeastward from the Mene Grande oil field. The type section is a very poor one since the base of the formation has been overlapped at this point by Pleistocene beds, while the top has been lost by synclinal erosion. Excellent exposures are present, however, in adjacent areas.

As described originally, the Paují formation included all Upper Eocene sediments lying above the Misoa formation in the general area of the Mene Grande oil field. Later observers noted that an effective three-fold division could be established to comprise a basal transition zone composed of interbedded sandstones, limestones and shale, a thick middle zone composed almost entirely of shale, and an upper zone of interbedded sandstone, reef limestones, and shale. Later still, the upper zone was removed from the Paují and named the Mene Grande formation. In this paper the lower zone is called Lower Paují, the middle zone Upper Paují.

Lithology.—The Lower Paují is composed of interbedded black shales and light gray to white sandstones. The sandstones, when fresh and unweathered, differ from those of the Misoa formation in being lighter in color, softer and non-quartzitic. They form the lower of the two oil zones in the Upper Eocene section of the Mene Grande field. Locally, orbitoidal reef limestones and sandy limestones may be present as in the Río San Pedro and Río Caús sections.

The Upper Paují consists very largely of black shales, commonly laminated, slightly arenaceous and pyritic, and in places containing calcareous, siliceous, or pyritic nodules. A zone of hard sandstones of varying thickness occurs in the middle of the Upper Paují and forms the higher of the two Upper Eocene petroliferous zones at Mene Grande.

Heavy minerals are relatively rare in the Paují formation. Muscovite, pyrite, and hematite are abundant; chlorite, magnetite, zircon, and tourmaline are fairly common.

Thickness.—Between the surface of the ground and the top of the Potreritos formation, 5,395 feet of Upper Paují were logged in Pica Pica Well No. 1 in eastern Bolívar. At least 400 feet of Lower Paují has been penetrated in the Mene Grande field without reaching the base of the formation. The Upper Paují in this field has a thickness of 2,500 feet, according to G. E. Tash (1937, p. 167). On the Río Caús in southwestern Trujillo the thickness of the Lower Paují measures 75 meters (246 feet). Near El Marfil on the Los Baños anticline slightly toward the northeast, the Upper Paují is at least 1,110 meters (3,641 feet) thick.

Stratigraphic relationship.—The Paují formation is conformable with the Misoa formation below, and apparently conformable but probably disconformable with the Mene Grande formation above.

Distribution.—The Upper Paují extends farther north than does the Lower Paují, as can be seen in the Pica Pica-1 section, where the Upper Paují has not yet passed by lateral transition into the Las Flores, although the Lower Paují has already disappeared by lateral transition into the Potreritos. The Paují formation crops out along the western flanks of the Serranía de Trujillo and Cerro Misoa in

the districts of Bolívar and Sucre, Zulia, and is found in wells in the southern part of the Bachaquero field in southern Bolívar and in the Mene Grande field in Sucre. In Trujillo the Paují is prominent on the Escuque and Los Baños anticlines and extends along the front of the Mérida Andes southwest past the Río Caús into the northern corner of the State of Mérida.

Age and paleontology.—The Upper Eocene (Jacksonian)age of the Paují formation is determined by the prolific marine fauna of small Foraminifera described by Nuttall (1935), to whose paper the reader is referred. The Paují has sometimes been called the *Uvigerina* zone because of the abundance of that foraminiferal genus.

The reef limestone member on the Río San Pedro contains the Upper Eocene large Foraminifera *Lepidocyclina* and *Discocyclina*, according to Liddle (1928, p. 237).

The reef limestone member on the Río Caús, according to Liddle (1928, p. 239), contains the following.

Discocyclina clarki (Cushman)
Discocyclina floridana (Cushman)
Pseudophragmina (*Proporocyclina*) *flintensis* (Cushman)

The generic names of the foregoing larger Foraminifera have been changed from those given by Liddle to bring them into harmony with the current classification.

The following macrofossils are all that have been identified from the Paují of Bolívar and Sucre.

Nucula sp.
Nuculana lisbonensis (Aldrich)
Arca sp.
Corbula sp.
Natica sp.
Turritella sp.
Ectinochilus gaudichaudi alauda (Olsson)

From sandy limestone and shale outcrops of the Lower Paují in the immediate vicinity of Pone Mesa in southwestern Trujillo, Winkler identified the following.

Ostrea sp.
Pinna sp.,
Cardium sp.
Cardium (*Trachycardium*) sp.
Pitar sp.
Latirus sp.
Architectonica sp.
Ectinochilus gaudichaudi alauda (Olsson)
Conus sp., cf. *C. sauridens* Conrad
Cancellaria sp.
Volvaria sp.
Dentalium sp.

From a sandy limestone bed near the top of the Lower Paují on the Río Caús near Las Pavas in southwestern Trujillo, Winkler has also identified the following.

Spondylus sp.
Plicatula sp.
Raetomya? sp.
Ectinochilus sp.

Correlation.—The Misoa-Paují transition beds, which G. E. Tash (1937, pp. 168, 171), following Blumenthal, places in the upper part of the Upper Misoa-Trujillo, are the equivalent of the Lower Paují of this paper, while his Paují (pp. 166–67) is the same as the Upper Paují of this paper. The Río Raya shale of Garner (1926, p. 681) is an early name for the Paují. The type section is along

the Río Raya, a stream north of the Río Paují in the District of Sucre, Zulia. The Los Baños shale of Garner (1926, p. 681) is another obsolete name for the Paují. The type section is on the Los Baños anticline in southwest Trujillo. The San Pedro formation of Liddle (1928, pp. 236–38) is a 2-foot bed of Upper Eocene orbitoidal limestone in the upper part of the lower Paují in the section along the Río San Pedro, situated between the Río Raya and the Río Paují in the District of Sucre, Zulia. The Río Caús formation of Liddle (1928, pp. 238–39) is the equivalent somewhat thicker orbitoidal limestone horizon in the upper part of the Lower Paují in the section along the Río Caús in southwest Trujillo. Both the San Pedro and Río Caús limestones should rank as local members of the Paují rather than as formations.

Correlatives of the Paují formation include the Zapa shale of Mackenzie (1937, pp. 263–64) in the State of Barinas on the southeastern flank of the Mérida Andes, and the Upper Eocene portion of the Carbonera formation in the Barco Concession and of the "Sandy Shale horizon" in Colón and southern Perijá. The Lower Paují is correlative with the Omuquena formation of Táchira and Mérida, the upper part of the Paso Diablo formation on the west side of the Manuelote syncline and the Barqueta member of the Mostrencos formation on the east side of the same syncline in northwest Zulia, the Potreritos formation of the districts of Bolívar, Miranda, Maracaibo, and Mara in northern Zulia and the El Paraíso formation of central Falcón. The Upper Paují is correlated with the Lobaterita formation of Táchira and Mérida, the La Sierra formation of the northern part of the District of Perijá in western Zulia, the combined Orumo formation and Taparito member of the Mostrencos formation of the Manuelote syncline in northwest Zulia, the Palmerejo formation in the southeast part of the District of Mara in northwest Zulia, the Las Flores formation in the districts of Bolívar, Miranda, Maracaibo, and Mara in northern Zulia, and the Tacal group of the District of Buchivacoa in western Falcón.

CARBONERA FORMATION (UPPER EOCENE AND MIDDLE OLIGOCENE)

The name Carbonera formation has recently been used by Notestein, Hubman, and Bowler (1944, pp. 1196–1201) to replace, in the Barco and Cucutá areas of Colombia, the prior terms "First Coal horizon" and "Sandy Shale horizon" of Liddle (1928, pp. 281–92), which are invalid because of their non-geographic derivation. Unfortunately, the Carbonera formation apparently includes strata of two different ages, Upper Eocene and Middle Oligocene, whereas the "First Coal" and "Sandy Shale" of the type section on the Tarra anticline, District of Colón, seem to be limited to the Upper Eocene. It is expected that further field work will make possible the extension into the Cúcuta, Barco, Colón, and southern Perijá areas of the terminology used in this paper for the equivalent section in Táchira.

The type section of the Carbonera formation is along the Quebrada Carbonera a tributary of the Río Zulia on the east flank of the Petrolea anticline in the

southeast corner of the Barco Concession, Colombia. The column figured by Notestein *et al.* can be correlated readily with both the Táchira and Colón sections. The coal measures at the base of the Carbonera formation are correlated with the "Second Coal horizon" at the base of the "Sandy Shale horizon" and the overlying thick sandstone in the Carbonera correlates with the Cubo sand of the "Sandy Shale horizon." This whole section is equivalent to the Omuquena formation in Táchira. The upper coal measures of the Carbonera correlate with the "First Coal horizon" in Colón. The strata lying between the top of the Cubo sand and the top of the "First Coal horizon" are correlated with the Lobaterita formation of Táchira. All of these correlations are between Upper Eocene beds. The highest 90 meters (295 feet) of the type section of the Carbonera consist of gray to buff, fine-grained, friable sandstones between which lie covered intervals. It is believed that these sandstones are Middle Oligocene in age and can be correlated lithologically with the Bebedero formation of Táchira. Certainly, the fossil locality 150 meters (492 feet) below the top of the Carbonera at El Cerrito, 7 kilometers northeast of Cúcuta, Colombia, from which the following macrofossils were identified by A. A. Olsson, appears to belong to the Middle Oligocene.

Arca (*Arginella*) cf. *puntabravoensis* Olsson
Ostrea sp.
Anomia n. sp.
Lucina sp.
Tagelus sp.
Pitar sp.
Clementia peruviana Olsson
Mactra sp.
Tellina sp.
Corbula sp.
Raetomya sp.
Ampullina bravoensis Olsson
Polinices n. sp.
Polinices (*Neverita*) cf. *subreclusiana* Olsson
Turritella n. sp., aff. *T. chira* Olsson
Cerithium? n. sp.
Cerithiella or *Cerithiopsis* sp.
Hannatoma emendorferi Olsson
Hannatoma n. sp., aff. *H. gesteri* (Hanna and Israelsky)
Pseudofaunus bravoensis Olsson
Cymia cf. *berryi* Olsson
Melongena n. spp.
Harrisianella cf. *peruviana* Olsson
Olivella sp.

The foregoing fauna is correlated with that of the Middle Oligocene Punta Bravo formation of northwestern Perú and with many other Middle Oligocene collections in the brackish-water to shallow-marine facies in northern South America. It is found slightly above a thick sandstone section which has sometimes been confused with the Mirador formation.

OMUQUENA FORMATION (UPPER EOCENE)

The name Omuquena formation is derived from the Río Omuquena in north central Táchira and is introduced at this time to designate an interbedded shale and sandstone formation that immediately overlies the gorge-forming Misoa formation a short distance downstream from the Las Talas-La Hojita trail crossing.

Lithology.—In the type section the Omuquena formation is composed of interbedded, greenish gray to dark gray, locally sandy, carbonaceous, plant-fossiliferous shales, and gray to greenish gray, locally laminated, fine-grained, indurated, carbonaceous, plant-fossiliferous, ripple-marked sandstones. The shales make up about two thirds of the formation. Beds of locally shaly coal up to 3 feet thick are present in the lower half of the formation. These correspond

with the so-called "Second Coal horizon" of the Colón District. Thin beds of hard, gray, locally fossiliferous limestone are in places present. The sandstones and sandy shales of the formation contain a simple heavy-mineral suite. Tourmaline, zircon, ilmenite, and zoisite are nearly always present; epidote and andalusite are present here and there, and feldspars are rare.

Thickness.—The Omuquena is 335 meters (1,098 feet) thick in the type area of northern Táchira. An increase to 520 meters (1,706 feet) is noted in the Río Lobaterita of west-central Táchira.

Stratigraphic relationship.—The Omuquena formation is transitional with the Mirador formation below and the Lobaterita formation above.

Distribution.—The Omuquena formation extends from western Táchira to west-central Mérida along the northwest flank of the Mérida Andes. Another less important outcrop area is in the Mucujún valley north of the city of Mérida in the central part of the State of Mérida.

Age and paleontology.—The Omuquena has been assigned to the Upper Eocene on paleontological evidence by both Olsson and Winkler. The impoverished brackish-water to shallow-marine microfauna consists of species of *Quinqueloculina*, *Ammobaculites*, *Trochammina*, and *Haplophragmoides*, and resembles the microfauna from the similar facies of the Potreritos formation in the northern part of the basin. Winkler has identified the following assemblages of macrofossils from several horizons in the middle part of the formation.

Río Omuquena, north-central Táchira. Sandy shale horizon 160 meters (525 feet) above base of formation.

Ostrea sp.
Lucina sp.
Clementia sp.
Pitar sp.
Tellina sp.
Macoma sp.
Spisula sp.
Raetomya sp.
Polinices sp.

Río Omuquena. Silty shale horizon 145 meters (476 feet) above base of formation.

Anomia sp.
Cyrena sp.
Venericardia sp.
Lucina sp.
Pitar sp.
Macoma sp.
Spisula sp.
Raetomya spp.

Río Escalante (Río Yegüines on some maps), District of Tovar, southwestern Mérida. Shale and limestone horizon 141 meters (462 feet) above base of formation.

Ostrea sp.
Anomia spp.
Cardium sp.
Thyasira sp.
Macoma sp.
Semele sp.
Psammosolen cf. *sancti-dominici* Maury
Mactra sp.
Spisula sp.
Labiosa sp.

Santa Rosa, 900 meters north northwest of Cañadón on the El Vigía-La Victoria road, District of Tovar, southwestern Mérida. Dark gray shale and carbonaceous sandstone.

Solemya sp.
Nuculana sp.
Cyrena sp.
Venericardia cf. *simillina* Olsson
Venericardia spp.
Cardium sp.
Lucina cf. *conventa* (Olsson)
Lucina sp.
Thyasira sp.
Meretrix sp.
Tellina sp.
Macoma sp.
Spisula sp.
Corbula sp.

Near the Mucujún power plant, northeast of the city of Mérida, central part of the State of Mérida. Dark gray sandy shale.

Anomia sp.
Cardium cf. *samanicum* Olsson
Lucina sp.
Corbula sp.
Ampullina sp.

Correlation.—The Omuquena formation is the exact equivalent of the lower part of the "Sandy Shale horizon," including the "Second Coal horizon" at its base as found in the states of Táchira and Mérida (Liddle, 1928, p. 285; Kehrer, 1938, p. 47). It apparently is correlated with the lower part of the Carbonera formation of Notestein, Hubman, and Bowler (1944, pp. 1196–1201) in the Barco region of Colombia and with the lower part of the type "Sandy Shale horizon" of Liddle (1928, pp. 281–85) in the District of Colón and the southern part of the District of Perijá, southwest Zulia. Other probable correlatives include the Lower Paují of Trujillo and southeastern Zulia, the Potreritos formation of northern Zulia, the upper part of the Paso Diablo formation on the west side of the Manuelote syncline and the Barqueta member of the Mostrencos formation on the east side of the same syncline in northwest Zulia, and the El Paraíso formation of central Falcón.

POTRERITOS FORMATION (UPPER EOCENE)

The name Potreritos is introduced at this time to designate an essentially shale and sandstone formation which crops out east of Lake Maracaibo near Potreritos ranch in the northwestern part of the District of Bolívar, Zulia. The formation comprises one of the major subdivisions of the Upper Eocene. Through wide usage the name has become firmly established in the nomenclature of the Bolívar Coastal field and adjacent areas.

Lithology.—In the Bolívar Coastal field the formation exhibits a near-shore brackish-water to shallow-marine type of deposition and is composed mainly of dark gray to black, carbonaceous, laminated, sandy shales, interbedded with fine white sandstones. Fine-grained to coarse and porous lenses and major sandstone beds are present in places. The most important of these is the porous "Main Sandstone" which has an average thickness of 200 feet and yields most of the oil found in the Eocene of the Bolívar Coastal area. Poor sorting is frequently noted and coarse quartz pebbles are commonly included in the finer sandstones. In the Netick oil field, west of Lake Maracaibo, the formation is in places lignitic and contains a number of sub-bituminous coal beds in its lower part. This same occurrence is noted in the outcrop area along both limbs of the Manuelote syncline in western Mara and Maracaibo districts, northwestern Zulia. The formation has not been penetrated completely in the Bolívar Coastal field and this unexplored basal section may contain equivalent coal beds.

Excellent heavy-mineral yields can generally be recovered from the sandy parts of the formation. A peculiarly etched garnet referred to as "dodecahedral" garnet is commonly present, and the formation is sometimes called the "Dodecahedral Garnet zone." The following is the complete heavy-mineral assemblage.

Abundant:	Muscovite, tourmaline, zircon, laucoxene
Common:	Chloritoid, "dodecahedral" garnet, magnetite, hematite (locally)
Scarce:	Barite (common locally), garnet, "pebbled" garnet (another type of etched garnet found in beds transitional with the overlying Las Flores formation), ilmenite, rutile, pyrite, and other opaques
Rare:	Anatase, brookite (locally common), chlorite, monazite, amphibole

Thickness.—The maximum thickness for the formation in the Bolívar Coastal field is estimated at 1,371 meters (4,498 feet). The formation has not been completely penetrated but Icotea well No. 1 in the northern part of the lake was bottomed in the formation after having penetrated 914 meters (3,000 feet). A tentative correlation indicates that an additional 366 meters (1,200 feet) are present. The formation thins to the north and west. In well No. 3 of the Netick field in south central Mara District, northwest Zulia, where an undisturbed section has been drilled, the thickness is 353 meters (1,158 feet).

Stratigraphic relationship.—In the Bolívar Coastal field it is believed that the Potreritos formation is transitional below with the Misoa. Westward, however, the Misoa formation wedges out, and in the La Paz-Netick-Tetones area of the districts of Maracaibo and Mara, the Potreritos is unconformable with the underlying Upper Paleocene Guasare formation. In the Manuelote syncline in western Mara and Maracaibo districts, the Potreritos is found again in transition with the underlying Misoa formation.

Where post-Eocene faulting and erosion have not interfered, the Potreritos is always comformable and gradational into the overlying Las Flores formation.

Distribution.—The known outcrop occurrences of the formation are limited to the area immediately adjacent to the Bolívar Coastal field in northwestern Bolívar and southern Miranda districts, and the Manuelote syncline of western Maracaibo and Mara districts. It is present in the subsurface of the Bolívar Coastal field and has been encountered in most of the wells drilled west and north of the city of Maracaibo, but is absent in the shallow basement area immediately east of the Los Ocho fault. With its equivalents, it is known in most of the outcrop areas surrounding the basin and is believed to underlie most of the basin.

Age and paleontology.—The age of the Potreritos formation is Upper Eocene. With the exception of the Misoa, it is the least fossiliferous of the Eocene formations of the Bolívar Coastal field. There the sandstones are commonly barren, except for local horizons of oyster shell fragments, and the few small Foraminifera contained in the shaly sediments belong to the arenaceous genera *Haplophragmoides*, *Ammobaculites*, *Ammomarginulina*, *Trochammina*, and *Textularia*. In the Bachaquero field of southern Bolívar a transition takes place between the foregoing sparse arenaceous microfauna and the prolific Paují microfauna, marking an increase in depth, salinity, and open-sea conditions from northwest to southeast. Northwest of the Bolívar Coastal field, starting in the Icotea well No. 1 section and continuing in the fields and wildcats of the District of Mara, a somewhat less abrupt transition takes place to a slightly deeper-water and more marine facies with the introduction of Ostracoda and calcareous Foraminifera of the genera *Quinqueloculina*, *Discorbis*, *Siphonina*, and *Anomalina*.

Some of the following rare macrofossils were identified by Hoffmeister and some by Winkler.

Nuculana sp.
Arca cf. *rhomboidella* Lea
Arca sp.
Ostrea sp.
Cardium sp.
Venericardia sp.
Corbicula sp.
Solen sp.
Tellina sp.
Spisula sp.
Corbula sp.
Turritella sp.
Fusinus sp.
Ectinochilus gaudichaudi alauda (Olsson)
Alectrion sp.
Clava sp.
Balanus sp.
Xanthopsis sp.

Correlation.—The Potreritos formation grades by lateral transition southeastward into the Lower Paují, the Misoa-Paují transition zone of Tash (1937, pp. 168, 171), who places it in the top of the Misoa formation. It can be correlated with the Omuquena formation in Táchira and Mérida, the lower part of the Carbonera formation in the Barco Concession, the lower part of the "Sandy Shale horizon" in Colón and southern Perijá districts, and the El Paraíso formation of central Falcón (Hodson, 1926, p. 3; Senn, 1935).

On the basis of heavy-mineral content, the Potreritos is the direct equivalent of the upper part of the Paso Diablo formation of Hedberg and Sass (1937, p. 91), according to Mas Vall, who has studied samples from the type section. On the opposite or eastern side of the Manuelote syncline, the lower or Barqueta member of the Mostrencos formation of Hedberg and Sass (1937, p. 92) is lithologically, mineralogically, and faunally identical with the Potreritos.

LOBATERITA FORMATION (UPPER EOCENE)

The upper part of the "Sandy Shale horizon" of Táchira and southwest Mérida (Liddle, 1928, p. 285; Kehrer, 1938, p. 47) is referred to here as the Lobaterita formation from its type exposure on the Río Lobaterita in the west central part of the State of Táchira. The base of the formation is at the top of the uppermost sandstone of the Omuquena formation at the river crossing of the Estación Táchira-Guavinas trail below Estación Táchira. The top is 1,030 meters (3,380 feet) downstream where the sandstone of the Bebedero formation first appears.

Lithology.—In the type section the Lobaterita formation is composed almost entirely of massive, dark greenish gray to dark gray, hard, platy shale. The shales are locally silty and sandy and commonly contain thin beds of hard, concretionary siltstone. Near the top of the formation some siltstones and in places fine-grained, indurated, carbonaceous sandstones are interbedded with the shales. Lateral change of facies is characteristic of the formation. Northward, in northern Mérida and western Trujillo, the formation consists almost entirely of massive, dark gray to black, conchoidally fracturing, rapidly weathering shales.

In the headwaters of Caño Frío, a tributary of the Río Onia in southwestern Mérida, the extreme upper part of the formation comprises a series of interbedded shale, limestone, sandstone, and coal. The sandstones, which have a maximum thickness of about 30 centimeters are light gray to greenish gray, hard,

carbonaceous, and plant-fossiliferous. The limestones, which have about the same thickness, are hard, dark gray, and fossiliferous. There are several bituminous coal beds having an average thickness of about 30 centimeters. This zone, which appears to be a local development only, may be correlated with the "First Coal horizon" of the District of Colón, Zulia.

The heavy minerals in the sandstones of the Lobaterita are generally few and non-diagnostic.

Thickness.—Wide variations in thickness of the Lobaterita formation and its equivalents are noted throughout the basin. This is due largely to the long period of erosion which followed the Upper Eocene deposition. At the type section on the Río Lobaterita, the thickness of the formation is 500 meters (1,640 feet). On the Río de Oro, in northern Táchira, it is 340 meters (1,115 feet).

Stratigraphic relationship.—The Lobaterita formation is everywhere gradational below into the Omuquena formation. The upper contact of the formation is unconformable with beds of the Middle Oligocene Bebedero or younger formations.

Distribution.—The Lobaterita formation is exposed in outcrops along the northwest flank of the Mérida Andes extending from the Río Lobaterita in west-central Táchira to a small *quebrada* that enters the Río Chama below Bolero in southwestern Mérida.

Age and paleontology.—The faunal evidence for the Upper Eocene age of the Lobaterita formation is rather scant. Macrofossils are rare, but a few specimens of *Venericardia* sp. were found in a dark gray shale 275 meters (902 feet) above the base of the formation on the Río Lobaterita and *Cardium* sp. has been reported from the Río Escalante section. The fossiliferous limestone in the "First Coal horizon" equivalent on Caño Frío in southwest Mérida contains numerous examples of *Ostrea* sp. The following Foraminifera were identified by Borger from the Río Lobaterita, Caño Frío, and Seboruco-Las Mesas road sections.

Haplophragmoides sp.
Ammobaculites spp.
Cyclammina sp.
Eggerella sp.
Trochammina sp.
Eponides sp.
Globigerina sp.
Anomalina sp.

Kehrer (1938, Spanish edition only, p. 48) mentions specimens of *Haplophragmoides*, *Trochammina*, *Bolivina*, and *Cibicides*.

Correlation.—The Lobaterita formation of the type section is correlated with the shales and sandy shales between the top of the Cubo sand and the base of the "First Coal horizon" which form the upper part of the "Sandy Shale horizon" of Liddle (1928, pp. 281–85) on the Tarra anticline in the District of Colón, Zulia. Due to the unconformity at the top of the Eocene, the Caño Frío section contains beds that are younger than any found in the type section and are correlated with the "First Coal horizon" of Liddle (1928, pp. 288–92). The type section of the Lobaterita is correlated with the Upper Paují of Trujillo and southeastern Zulia.

It can not be stated at present whether the "First Coal horizon" and the equivalent beds on Caño Frío should also be correlated with the Upper Paují or whether they represent the depositional cycle of the younger Eocene Mene Grande and Ambrosio formations. In the latter case the Caño Frío beds would have to be removed from the Lobaterita formation.

The Lobaterita is correlative with the middle part of the Carbonera formation of Notestein, Hubman, and Bowler (1944, pp. 1196–1201) in and south of the Barco Concession, Colombia; with the La Sierra sandstone of Hedberg and Sass (1937, pp. 89–90) in northern Perijá District, western Zulia; with the combined Orumo formation and Taparito member of the Mostrencos formation of Hedberg and Sass (1937, pp. 91–95) in the Manuelote syncline of Mara and Maracaibo districts, northwest Zulia; with the Las Flores formation of northern Zulia; and with the Tacal group of Gonzalez de Juana (1938, pp. 126–27) in the District of Buchivacoa, western Falcón.

LAS FLORES FORMATION (UPPER EOCENE)

The name Las Flores is derived from the small settlement of the same name in the northern part of the District of Bolívar, Zulia, east of Lake Maracaibo. The term was applied originally to sandstones which crop out in the immediate vicinity. These beds were later recognized in well sections of the Bolívar Coastal field. In its present use the name defines one of the major divisions of the Upper Eocene and has become firmly established in the Bolívar Coastal field and adjacent areas.

Lithology.—The Las Flores formation is a shallow-water facies of the Upper Paují. It is composed of gray to dark gray, finely laminated, pyritic, carbonaceous shale, interbedded with fine-grained, light gray sandstone. The shales weather to light gray clay much used for manufacturing bricks. Lenticular horizons of medium- to coarse-grained sandstones are commonly present. The formation exhibits a shallow-marine to brackish-water type of sedimentation.

Excellent heavy-mineral yields are obtained from the sandy parts of the formation. They are generally characterized by the presence of a distinctly etched or "pebbled" garnet which has led to the designation of the Las Flores interval as the "Pebbled Garnet zone." The following is the complete mineral suite.

Abundant:	Tourmaline, zircon, leucoxene
Common:	Chloritoid, "pebbled" garnet, staurolite, magnetite, ilmenite
Scarce:	Barite, brookite, "dodecahedral" garnet (in the basal beds transitional with the Potreritos), rutile, hematite, muscovite
Rare:	Amphibole, anatase, biotite, chlorite, clinozoisite, sillimanite

Thickness.—The thickness of the Las Flores formation is extremely variable in view of the post-Eocene erosion which has in many places, removed it entirely. The maximum thickness encountered in the Bolívar Coastal field is in Icotea well No. 1, where 1,308 meters (4,290 feet) of the formation was penetrated. West and north of the city of Maracaibo on the west side of the lake, the formation is

much thinner and in places entirely missing. Well No. 101 in La Concepción field encountered 569 meters (1,867 feet) and well Netick No. 2, 21 kilometers northwest, penetrated 407 meters (1,335 feet) of the formation. In both of these areas the formation is buried beneath a thin mantle of younger beds.

Stratigraphic relationship.—The Las Flores formation is everywhere conformable and gradational with the underlying Potreritos formation. It is generally impossible to define the contact with reliable accuracy, but in practice the boundary is usually set at the point where the grains of "pebbled" garnet first consistently outnumber the grains of "dodecahedral" garnet.

Throughout the northern part of the Bolívar Coastal field, the Las Flores is overlain unconformably by the Upper Eocene Ambrosio formation, while in the District of Miranda on the north it is overlain unconformably by the Upper Eocene Churuguarita formation. Elsewhere, Middle Oligocene or younger formations rest unconformably on the Las Flores.

Distribution.—Outcrop occurrences of the formation are common along the eastern side of the basin in the area northeast and north of the Bolivar Coastal field. The two principal ones are the type area of the Las Flores in northern Bolívar and the area south and east of Maneta in central Miranda (Liddle, 1928, p. 245; Gonzalez de Juana, 1938, p. 127). The Las Flores is an important subsurface formation in the Bolívar Coastal field, passing by lateral transition into the Upper Paují eastward (at Pica Pica-1) and southward (in the Bachaquero field). On the south shore of Toas Island the Las Flores is in fault contact with the Middle Cretaceous Apón limestones.

On the west side of the lake isolated areas of outcrop are found in the vicinity of the city of Maracaibo. Among these are a small area between the barracks and the docks within the city itself; a large area on the Cojoro structure, badly eroded by Cañada Honda and its tributary intermittent streams, about 4 kilometers west of the city, and a medium-sized area on the Sibucara structure 5 kilometers farther west. North of Maracaibo along the shore of the lake additional exposures occur between Punta de Piedras and Santa Rosa and again between Santa Cruz and Palmarejo. The Las Flores crops out on the crests of the Cañadones, Kilometer-24, Tetones, and Netick structures in the District of Mara and is found slightly below the surface in the La Concepción field in the District of Maracaibo. In the La Paz field, 20 kilometers northwest of the La Concepción field in the same District, the Las Flores is missing through erosion, and the Potreritos and Guasare formations appear on the faulted crest of the structure. The Las Flores is also wanting in the shallow basement area east of the Los Ocho fault but reappears along both limbs on the Manuelote syncline on the west. Many wildcat wells in the District of Urdaneta have penetrated into the Las Flores.

Age and paleontology.—An upper Eocene age has been assigned to the Las Flores formation on the basis of faunal content and stratigraphic position. Small Foraminifera and Ostracoda are fairly common and so are macrofossils locally. In the landward or northeast half of the Bolívar Coastal field, *Textularia hockley-*

ensis Cushman and Applin is locally so common, especially in the upper part of the formation, that the Las Flores has often been called the *Textularia* zone. *Textularia adalta* Cushman occurs in both the Las Flores and Potreritos. The lower half of the Las Flores formation, wherever it has been encountered, contains numerous specimens of *Trochammina teasi* Cushman and Ellisor, which are frequently distorted or collapsed like the figured type. For that reason, this part of the section has been known as the *Trochammina* subzone. Occasional specimens of this species may be observed in the Potreritos formation. In Mara and Maracaibo districts the Las Flores can often be divided into a lower *Trochammina* zone, a middle *Quinqueloculina* zone, and an upper zone in which both these genera are lacking.

The following microfossil genera have been noted in the Las Flores.

Ammobaculites
Ammodiscus
Ammomarginulina
Anomalina
Bathysiphon
Cibicides
Discorbis
Elphidium
Eponides
Frondicularia
Globigerina
Globigerinella
Globigerinoides
Globulina
Haplophragmoides
Lagena
Quinqueloculina
Siphonina
Textularia
Trochammina
Uvigerina
Bairdia
Cythereis
Cytherella
Cytherelloidea
Cytheridea
Cytherideis
Eocytheropteron
Eucythere
Loxoconcha
Paracypris
Pyricythereis

The following macrofossils have been identified from the Las Flores by Hodson, Hoffmeister, and Winkler.

Arca spp.
Cardium tuomeyi Aldrich
Cardium spp.
Clementia spp.
Corbicula sp.
Corbula cf. *arnoldi*
Corbula spp.
Macrocallista sp.
Meretrix subimpressa var. *golfotristensis* Maury
Meretrix sp.
Nucula sp.
Nuculana lisbonensis Aldrich
Nuculana spp.
Ostrea sellaeformis Conrad
Ostrea tacalensis Hodson
Ostrea sp.
Pecten sp.
Pitar sp.
Psammobia sp.
Semele sp.
Solen sp.
Tellina spp.
Thracia sp.
Venericardia sp.
Alectrion terebratula Olsson
Alectrion sp.
Amauropsis smithiana Maury
Architectonica sullana Olsson
Calyptraea sp.
Cypraea sp.
Diastoma americanum Olsson
Dorsanum sp.
Ectinochilus gaudichaudi alauda Olsson
Epitonium cf. *multiliniferum* Aldrich
Fusinus sp.
Natica sp.
Rimella knappiana Maury
Rimella spp.
Scaphella sp.
Turritella spp.
Dentalium cf. *microstria* Heilprin
Hercoglossa sp.
Xanthopsis sp.

Correlation.—The El Mene formation was originally the exact equivalent of

the combined Ambrosio, Las Flores, and Potreritos formations, but later the Ambrosio was recognized as a separate formation in the subsurface of the Bolívar Coastal field, and the El Mene was restricted to the combined Las Flores and Potreritos. The type locality, El Mene de Ambrosio on the east shore of the lake north of Ambrosio, District of Bolívar, lies within the outcrop area of the Ambrosio formation. Hedberg and Sass (1937, p. 93) state that the El Mene in the wells of the Bolívar Coastal field must be correlated with their Mostrencos formation. The name El Mene is objectionable because it has been used in Venezuela for several entirely distinct formations.

The Las Flores formation is the exact equivalent of the combined Orumo formation and Taparito member of the Mostrencos formation of Hedberg and Sass (1937, pp. 91–95) in the Manuelote syncline of northwest Zulia. As previously explained, the underlying Barqueta member of the Mostrencos formation is the Potreritos equivalent. The type localities of the Orumo, Mostrencos, and Taparito are all small ranches on the east limb of the syncline and are situated from northeast to southwest in the order given. Hedberg and Sass correctly correlate the Mostrencos with the El Mene of the wells of the Bolívar Coastal field (Las Flores and Potreritos), but they correlate the Orumo with the Ambrosio of the well sections rather than with the top part of the El Mene of the well sections. They state that the Orumo is paleontologically similar to the Mostrencos but mineralogically resembles the Ambrosio. According to Dusenbury, the Orumo microfauna resembles that of the Mostrencos and the Las Flores, and is quite different from that of the Ambrosio. According to Mas Vall, sandstone samples collected at the Orumo type locality yield a typical Las Flores heavy-mineral suite. Different methods of preparation of the heavy-mineral slides or contamination with Miocene heavy minerals may account for these diverse results.

Two other exact equivalents of the Las Flores are the Palmarejo beds of Liddle (1928, pp. 303–07) and the Cañadones formation of Garner (1926, p. 682). The Palmarejo beds receive their name from the outcrops between Palmarejo and Santa Cruz on the west shore of the lake 20 kilometers north of Maracaibo. The type locality of the Cañadones formation is the crest of the Cañadones structure a few kilometers northwest and, like Palmarejo, situated in the southeast part of the District of Mara. At both places fossils were found which were misidentified as Middle Miocene in Liddle's publication.

The Las Flores passes southeastward into the Upper Paují by lateral transition in the Bachaquero oil field of southern Bolívar. It is correlated with the Paují shale of Tash (1937, p. 166) in the Mene Grande oil field in the District of Sucre, the Upper Paují of Trujillo, the Lobaterita formatiõn of Táchira and Mérida, the middle part of the Carbonera formation in and south of the Barco Concession, the upper part of the "Sandy Shale horizon" of Colón and southern Perijá districts, the La Sierra formation of Hedberg and Sass (1937, pp. 89–90), and the Tacal group of Gonzalez de Juana (1938, pp. 126–27) in the District of Buchivacoa, western Falcón.

LA SIERRA FORMATION (UPPER EOCENE)

The type section of the La Sierra formation of Hedberg and Sass (1937, pp. 89–90) is exposed along the road on the north side of the Río Negro where the river cuts through the frontal ridge of the Sierra de Perijá one kilometer east of Rancho La Sierra. Here there are 110 meters (361 feet) of hard, white to light gray, medium- to coarse-grained sandstone and a few intercalations of shale and sandy shale. On weathering, the sandstones become friable and are stained maroon or buff by iron oxide. In other sections lenses of fine conglomerate have been observed within individual beds of coarse sandstone.

No fossils have ever been found in this formation, but, according to Mas Vall, samples from the type section yield a typical Las Flores suite of heavy minerals. On this evidence alone the La Sierra is regarded as a littoral facies of the Las Flores and its equivalents. In the type area the formation rests on the Río de Oro member of the Mito Juan formation with apparent conformity, but on the Río Cogollo and Quebrada La Luna it lies on the La Luna, while on the Río La Ge it is found in contact with limestones of the Cogollo group. Therefore, the base of the La Sierra is considered unconformable, and it is believed that the equivalents of the Potreritos, Misoa, Trujillo, and Guasare have been completely overlapped. The top of the La Sierra is unconformable with the Middle Oligocene El Fausto formation, or with non-marine Miocene formations where the El Fausto is absent.

The "Frontal sandstone" of Hedberg and Sass (1937, p. 95) includes the La Sierra formation and the basal part of the El Fausto formation.

AMBROSIO FORMATION (UPPER EOCENE)

The name Ambrosio, introduced into print by Hedberg and Sass (1937, p. 95), is derived from the village of the same name on the eastern shore of Lake Maracaibo in the northern part of the District of Bolívar, Zulia. It was used originally to describe an essentially shale formation found in the subsurface of the Ambrosio field, now the northern end of the Bolívar Coastal field. Since that time weathered outcrops of the formation have been recognized along the lake shore near El Mene de Ambrosio and El Mene well No. 1.

Lithology.—In the subsurface the formation is composed largely of interbedded shales, clay shales, and siltstones. Mottling is common in the shales and clay-shales, and the colors range through brown, purple, buff, and bluish gray. The siltstones are generally light green and commonly friable, carbonaceous, and micaceous. Beds of greenish gray to buff, mottled, locally micaceous and iron-stained, friable sandstone have been noted in the outcrops. A few fossiliferous calcareous shales and sandstones were discovered in the subsurface of the deepest part of the Icotea syncline. The lithology varies widely over short distances.

An analysis of the sandy parts of the formation shows the following heavy-mineral suite.

Abundant:	Magnetite, muscovite, barite (locally), and hematite
Common:	Limonite, chloritoid, epidote, leucoxene, tourmaline, and zircon
Scarce:	Rutile, staurolite, titanite, and ilmenite
Rare:	Amphibole, anatase, andalusite, brookite, chlorite, clinozoisite, garnet, glaucophane, kyanite, and pyrite

In view of the persistent (though scarce) presence of titanite throughout the formation, it is sometimes referred to as the "Titanite zone."

The type of sedimentation is shallow marine to brackish water.

Thickness.—The thickness of the formation in the subsurface varies from 0 to 111 meters (0 to 363 feet). The maximum thickness was found in the deepest part of the Icotea syncline.

Stratigraphic relationship.—An unconformable relationship exists between the Ambrosio and the underlying Las Flores or Potreritos formations. The period of non-deposition was probably short, but erosion must have locally been intense in order to remove the entire thickness of the Las Flores.

The Ambrosio is overlain unconformably and with high angularity either by the Middle Oligocene Icotea formation or by the Lower Miocene La Rosa formation. This is the greatest of the Tertiary unconformities in the Maracaibo basin.

Distribution.—The outcrop occurrence of the Ambrosio formation is limited to the El Mene area adjoining the northeast shore of Lake Maracaibo and north of the Ambrosio section of the Bolívar Coastal field. Northeastward the Ambrosio is covered by younger Tertiary deposits and according to evidence obtained in cores recovered from test holes, passes laterally into the Churuguarita formation. Toward the south and southwest it likewise disappears beneath the younger Tertiary formations and toward the south and west pinches out against the post-Eocene unconformity. Southwestward it is well developed in the Icotea syncline and extends thinly over a wide area of the lake in the La Rosa and northern Punta Benitez sections of the Bolívar Coastal field, until it again pinches out at the post-Eocene unconformity. Isolated patches of Ambrosio formation occur in fault blocks on the on-shore subsurface in the La Rosa and northern Lagunillas sections of the field.

Age and paleontology.—The age of the Ambrosio formation is Upper Eocene. The basal part is unfossiliferous and, for this reason, over large areas the Ambrosio can be detected only by lithology or heavy-mineral analysis. The middle portion contains a large microfauna of the following mingled arenaceous and calcareous genera of Foraminifera.

Ammobaculites
Ammomarginulina
Bathysiphon
Haplophragmoides
Textularia
Verneuilina
Anomalina
Camerina
Dentalina
Discocyclina
Globulina
Guttulina
Gyroidina
Lagena
Nonion
Nonionella
Pyrulina
Quinqueloculina
Siphonina

The highest portion of the Ambrosio contains only the first seven of these genera. Since *Anomalina* is the commonest fossil in the Ambrosio, the formation is sometimes referred to as the *Anomalina* zone. The presence of *Camerina* and *Discocyclina* in the middle of the formation indicates conditions of shallow, warm-water, marine deposition. The basal unfossiliferous part of the formation probably represents fresh-water deposition, while the zone of arenaceous Foraminifera at the top bears witness of a brackish-water to shallow-marine habitat. It is this upper zone which crops out on the lake shore at El Mene de Ambrosio.

The following macrofossils have been found in surface samples designated as Ambrosio.

Arca sp.
Corbula sp.
Nuculana spp.
Pinna sp.
Pitar sp.
Tellina sp.
Venericardia sp.
Alectrion sp.
Architectonica sp.
Malea sp.
Olivella sp.
Turritella spp.

Correlation.—The Ambrosio is identical with the original El Mene formation at the El Mene's type locality exposures but is younger than the restricted El Mene of Hedberg and Sass (1937, p. 93) in the subsurface of the Bolívar Coastal field. It is correlated with the Churuguarita formation of the District of Miranda on the north and with the Mene Grande formation of the District of Sucre on the south. The Paloma Alta series of Senn (1935, p. 60), consisting chiefly of shales unconformably overlying the Paují shales in the southeastern part of the District of Bolívar, should probably be included in the Ambrosio formation.

MENE GRANDE FORMATION (UPPER EOCENE)

The name Mene Grande formation, first published by Garner (1926, p. 682), was applied to a series of alternating calcareous sandstones and gray shales lying on the Paují shales in the Mene Grande oil field, District of Sucre, southeast Zulia. Tash (1937, pp. 165–70) gives the first full description of the formation and states that the best section is found in a small *quebrada* which originates near the north end of the Mene Grande oil seep and runs west toward the lake.

Lithology.—The sandstones of the Mene Grande formation are ordinarily calcareous and have a light bluish gray color when fresh and unweathered. The interbedded shales are very much like those of the underlying Paují but are generally lighter in color. Reefs and lenses of orbitoidal limestone are in places encountered intercalated with the sandstone.

Thickness.—According to Tash, the Mene Grande varies in thickness from 75 meters (246 feet) to 475 meters (1,558 feet).

Stratigraphic relationship.—The Mene Grande rests on the Paují with apparent conformity but probable disconformity. It is covered discordantly by the non-marine Miocene Isnotú formation.

Distribution.—The Mene Grande crops out on the Colina de Mene Grande and extends from the Río San Pedro northward as far as the Santa Barbara-Los

Barrosos road. The formation is not known outside of the District of Sucre.

Age and paleontology.—Nuttall has established a distinct faunal break between the Paují and Mene Grande formations (Tash, 1937, p. 170), and it is believed that this break probably marks a disconformity of minor importance. The Mene Grande, like the Paují, is Upper Eocene in age, and both formations have many foraminiferal species in common. However, the Mene Grande can be readily distinguished by the presence of certain species of orbitoids and certain species of *Bathysiphon*, *Bulimina*, *Cassidulina*, *Cibicides*, *Clavulina*, *Dorothia*, *Globigerina*, *Spiroplectammina*, *Textularia*, *Trochammina*, *Uvigerina*, *Verneulina*, and *Valvulina*, according to Tash. Some of the arenaceous species appear to have been reworked from the Upper Cretaceous.

Senn (1935, p. 58) lists the following larger Foraminifera identified by Tobler, Douvillé, and Gorter and Van der Vlerk from the Mene Grande reef limestones exposed on the Río San Pedro.

Pseudophragmina (*Proporocyclina*) *flintensis* (Cushman)
Discocyclina (*Asterocyclina*) *georgiana* (Cushman)
Discocyclina (*Asterocyclina*) *asterisca* (Guppy)
Discocyclina (*Asterocyclina*) *vaughani* (Cushman)
Discocyclina (*Asterocyclina*) *maracaibensis* Gorter and Van der Vlerk
Lepidocyclina (*Pliolepidina*) *kugleri* Gorter and Van der Vlerk
Lepidocyclina (*Pliolepidina*) *trinitatis* Douvillé
Lepidocyclina (*Pliolepidina*) *pustulosa* (Douvillé)
Lepidocyclina (*Pliolepidina*) sp.
Helicolepidina spiralis Tobler
"*Nummulites* cf. *floridensis Heilprin*"
Operculina sp.
Spiroclypeus sp.
Dictyoconus sp.

With the exception of the "Nummulites," which is probably an *Operculinoides*, the generic and subgeneric nomenclature employed by Senn has been revised in harmony with the most recent usage. In addition, it should be noted that Vaughan (1945, p. 111) places *Discocyclina* (*Asterocyclina*) *maracaibensis* Gorter and Van der Vlerk, 1932, in synonymy with *D.* (*A.*) *aurarensis* Hodson, 1926, and that Vaughan and Cole (1941, p. 65) include *Lepidocyclina kugleri* Gorter and Van der Vlerk, 1932, and *L. trinitatis* Douvillé, 1923, in the synonymy of *L. pustulosa* (Douvillé), 1917. According to Senn, the fauna is Upper Eocene and comparable with those of the Ocala limestone of Florida and the Mount Moriah formation of Point Bontour, Trinidad, and the Upper Eocene of Soldado Rock.

Correlation.—The Mene Grande formation is correlated with the El Mene formation of Mackenzie (1937, p. 264), named for the Río El Mene (Río Quiu on some maps) in the State of Barinas. Since Mackenzie's paper was written, numerous specimens of *Raetomya* have been discovered in the El Mene, which is therefore now considered Upper Eocene instead of Lower Miocene. As it overlies the Zapa shale, which contains a good Paují microfauna, the correlation with the Mene Grande seems assured. In order to avoid confusion with the several other Venezuelan formations of the same name, the El Mene formation was renamed

the Altamira formation by the geologists of the Sinclair Oil Company shortly after the publication of Mackenzie's paper. The name Altamira until now has appeared only in company reports and is here recommended for general adoption.

The Mene Grande formation is also correlated with the Paloma Alta series of Senn (1935, p. 60) in the southeastern part of the District of Bolívar, the Ambrosio formation in the northern part of the District of Bolívar, and the Churuguarita formation in the District of Miranda.

CHURUGUARITA FORMATION (UPPER EOCENE)

Garner (1926, p. 681) first employed in print the name Churuguarita limestone for a formation of alternating clay shales and algal-orbitoidal reef limestones exposed near the small abandoned ranch of Churuguarita in the southern part of the District of Miranda, northeastern Zulia.

Lithology.—The dark gray to light bluish gray clay shales do not crop out but were observed in exploratory pits dug in the strike valleys between the ridge-forming limestone members, of which there are at least four of major importance. The clay shales contain here and there thin beds of tan to gray, fine- to medium-grained, soft sandstones, and are locally sandy throughout. A few dense black shales occur, commonly near the limestone reefs. The latter form low strike ridges which locally develop into knobs where the calcareous algae are most abundant. The algae are commoner in the lower reefs than in the upper ones, where the orbitoids are more varied and more numerous. The reef limestones are massive and non-bedded, white in color and pitted on weathered surface. Above the highest limestone the clay shales become bleached, gypsiferous, and lignitic, indicating a change from marine to brackish-water and salina deposition.

Thickness.—The Churuguarita formation thickens from about 1,216 meters (4,000 feet) at the type locality to about 1,677 meters (5,500 feet) to the east where it is covered by the Miocene. The interval of 976 meters (3,200 feet) between the base of the lowermost limestone and the top of the uppermost limestone remains constant, and the increased thickness is due to the appearance of new beds below the unconformity at the top of the formation.

Stratigraphic relationship.—The Churuguarita formation crops out on the eastward-plunging Churuguarita anticline, of which the Las Flores formation forms the core. The Churuguarita is unconformable with the Las Flores, at the top of which there is a boulder bed. South and east of the structure the Churuguarita is overlain unconformably by the Lower Miocene La Rosa formation, north of the structure by the Middle Oligocene La Victoria formation.

Distribution.—The formation outcrops only for a distance of 22 kilometers between the Río Palmar on the east and a point slightly west of the ranch known as El Zamuro in the northernmost part of the District of Bolívar. The bulk of the outcrop area lies in the southern part of the District of Miranda in northeastern Zulia.

Age and paleontology.—The Churuguarita formation is of Upper Eocene age.

Its orbitoidal fauna has been described by Helen K. Hodson (1926). All of her specimens from localities in the District of Miranda, Zulia, are from the Churuguarita formation. The reader is referred to Vaughan and Cole (1941) and to Vaughan (1945) for later changes in both generic and specific nomenclature.

The following macrofossils have been identified from the Churuguarita limestones.

Tubulostium clymenoides (Guppy)
Echinolampas ovumserpentis Guppy
Echinolampas sp.
Eupatagus sp.
Modiolus alabamensis Aldrich
Panope sp.
Pecten cf. *choctavensis* Aldrich
Pecten sp.
Pitar spp.
Amauropsis cf. *guppyi* Gabb
Amauropsis ocalana Dall
Scaphander (*Bucconia*) *grandis* Aldrich
Turritella sp.

Correlation.—The Churuguarita formation is correlated with the combined Santa Rita conglomerate (Senn, 1935, p. 60) and Jarillal shale (Senn, 1935, p. 62) of southern Falcón and the Cerro Campana beds (Senn, 1935, p. 68) of eastern Falcón. Other correlatives are the Ambrosio formation in the northern part of the District of Bolívar, the Paloma Alta series in southeastern Bolívar, the Mene Grande formation in Sucre and the El Mene formation of Mackenzie in Barinas.

OLIGOCENE

ICOTEA FORMATION (MIDDLE OLIGOCENE)

The name Icotea is derived from Punta Icotea on the east side of Lake Maracaibo between the villages of La Rosa and Ambrosio. It is used to define a silt and claystone formation which occurs in the subsurface of the Icotea syncline of the northern Bolívar Coastal field (Haas and Hubman, 1937, pp. 126–27). According to Hedberg and Sass (1937, p. 97), the formation was named by geologists of the Gulf Oil Company.

Lithology.—The formation is composed of hard, massive, in places carbonaceous, white to light gray, fine sandstones, siltstones, and claystones. It is locally mottled light green, yellow, and brownish red. Beds of green or gray shale and sandstone are present here and there. Its heavy-mineral suite comprises zircon, tourmaline, ilmenite, leucoxene, rutile, and staurolite. An abundance of zircon and a relative scarcity of other heavy minerals are characteristic.

The exact type of sedimentation is still a matter of conjecture. An eolian origin with subsequent deposition in lakes or lagoons has been suggested, followed by elevation and a long period of weathering to account for the white color and the mottling.

Thickness.—The thickness of the formation varies from 0 to 200 meters (0 to 656 feet). The maximum development is in the Icotea syncline in the northern part of the Bolívar Coastal field.

Stratigraphic relationship.—The formation is underlain unconformably by beds of the Upper Eocene and overlain unconformably by the La Rosa formation (Lower Miocene). It grades laterally westward into the El Fausto formation.

Distribution.—The Icotea formation is locally present throughout the north-

ern part of the Bolívar Coastal field and extends westward across Lake Maracaibo, where its thickness does not exceed 50 meters (164 feet). It occupies synclinal areas and depressions in the old Eocene land surface.

Age and paleontology.—The Icotea formation has been assigned to the Oligocene on the basis of its stratigraphic position. It contains no indigenous fauna, but rare reworked Eocene arenaceous Foraminifera are present. Since no Lower or Upper Oligocene fossils have ever been encountered in the Maracaibo basin, while Middle Oligocene brackish-water fossils have been found in the Carbonera and La Victoria formations, the probability is that the Icotea belongs to the same Middle Oligocene cycle of deposition.

Correlation.—The Icotea grades laterally westward into the El Fausto formation in the District of Perijá. It is probably equivalent to the Bebedero formation of Mérida and Táchira and to the upper part of the Carbonera formation of the Barco Concession. Another correlative is the La Victoria formation of the District of Miranda, the upper part of which has a close lithologic similarity to the Icotea.

LA VICTORIA FORMATION (MIDDLE OLIGOCENE)

The name La Victoria formation, although published here for the first time, is by no means new and was used in company reports, dated 1926, by L. G. Weeks and other geologists and paleontologists of the Standard Oil Company of Venezuela. The type locality is the outcrop of *Hannatoma* limestone in the La Victoria road half a kilometer west of the ranch of La Victoria in the south central part of the District of Miranda, northeastern Zulia.

Lithology.—The limestone at the type locality is of brackish-water to semimarine origin, but the bulk of the formation appears to be of non-marine, probably lacustrine character. These fresh-water sediments consist of clays, clay shales, silts, and sandstones, the latter being commonest around the margins of the basin of deposition. The finer sediments are mostly dark shades of gray, bluish gray, brown and maroon, and in places exhibit mottling. The dull-colored mottled clays of this formation are readily differentiated from the more brightly colored mottled clays of the Middle Miocene. White, gray, light brown, and dark reddish brown, fine-grained sandstones are found interbedded with the clays and shales. Only one 2-foot limestone was logged near the top of the formation in La Victoria No. 1, a well near the type locality, but in Miranda No. 1 on the Cueva del Tigre structure in eastern Miranda several limestones and calcareous horizons were encountered in the upper part of the La Victoria section. Were it not for the presence of these thin limestones and a number of lignitic coals, it would be difficult to differentiate the top part of the formation in Miranda No. 1 from the Icotea formation, for weathering at the Oligocene-Miocene unconformity has apparently bleached most of the clay shales, silts, and sandstones white to a depth of several hundred feet. Below this bleached zone the sediments resemble those in La Victoria No. 1 and those of the El Fausto formation.

Thickness.—About 610 meters (2,000 feet) was estimated by Weeks as the

thickness of the outcropping section. This figure is too low, at least for the center of the basin of deposition, for 2,195 feet of La Victoria formation was found in La Victoria No. 1 and 2,694 feet in Miranda No. 1 without reaching the bottom of the formation in either case.

Stratigraphic relationship.—The La Victoria formation lies unconformably upon the Las Flores and Churuguarita formations and unconformably beneath the La Rosa or younger formations.

Distribution.—The La Victoria formation crops out in the synclinal basin between the Maneta uplift on the north and the Churuguarita anticline on the south. On the west it is covered by the La Puerta and El Milagro formations, to the east by the La Rosa formation. The entire area of outcrop is confined to the south-central part of the District of Miranda, northeastern Zulia. In the subsurface the La Victoria extends eastward at least as far as Miranda No. 1 on the Cueva del Tigre anticline in the eastern part of the District of Miranda.

Age and paleontology.—The age of the La Victoria formation is Middle Oligocene, the evidence for this determination consisting of the presence of large numbers of the gastropod *Hannatoma emendorferi* Olsson in the limestone at the type locality. Originally described from the Middle Oligocene Punta Bravo formation of Perú, this species also occurs in the brackish-water facies of the Middle Oligocene at Cúcuta, Colombia, and in the Río Boconó section in Barinas.

Correlation.—The La Victoria is correlated lithologically and stratigraphically with the Icotea formation of the Districts of Bolívar and Urdaneta and the El Fausto formation of the District of Perijá. It is correlated paleontologically with the upper part of the Carbonera formation of the Barco and Cucutá areas, and the Carbonera in turn is correlated lithologically with the Bebedero formation. The so-called "Monte Claro Signal sands" of the Monte Claro oil field in the center of the District of Buchivacoa are probably correlative with the La Victoria. Farther east the Middle Oligocene becomes marine in the districts of Democracia and Bolívar in central Falcón with the appearance of the San Luis limestone, Pecaya shale, and San Juan de la Vega sandstone (Liddle, 1928, pp. 251–60; Senn, 1935, p. 71).

EL FAUSTO FORMATION (MIDDLE OLIGOCENE)

The term El Fausto is used to designate a predominantly siltstone and claystone formation that crops out at the ranch of El Fausto, five kilometers west from the settlement of El Rodeo in the District of Perijá, Zulia. According to Hedburg and Sass (1937, pp. 95–97), the name was used first by geologists of the Richmond Petroleum Company.

Lithology.—The formation is composed typically of claystones and siltstones that are mottled red, purple, gray, green, and brown. Present are subordinate amounts of gray, green, and dark gray shale or claystone, and greenish gray, fine-grained sandstone, weathering red or brown.

The formation exhibits a wide vertical and lateral variation in its heavy-

mineral assemblage. Ilmenite, zircon, tourmaline, and rutile are consistent, while garnet, staurolite, kyanite, andalusite, epidote, and chloritoid may or may not be present.

The type of sedimentation is fresh- to brackish-water with probably some true continental deposits such as alluvial fans, cones, and outwash-plain material along the Perijá mountain front, especially in the lower part of the formation.

Thickness.—At the type locality the thickness of the formation is about 1,300 meters (4,265 feet).

Stratigraphic relationship.—The El Fausto is overlain by the Los Ranchos formation with no apparent unconformity. A disconformity is postulated however, since the La Rosa has been overlapped by the Los Ranchos formation and is missing in the type El Fausto area.

The El Fausto rests unconformably on the Upper Eocene La Sierra and older formations.

Distribution.—The formation is poorly exposed in the plain along the Sierra de Perijá front from a point about half way between Río Palmar and Río La Ge almost to the Río Macoita in west-central Perijá District, and thins rapidly eastward in the subsurface area of its occurrence.

Age and paleontology.—The only fossils that have ever been found in the formation are a few brackish-water Foraminifera and Ostracoda, rare fish and crustacean remains, the brackish-water pelecypod *Corbula* and reworked Cretaceous Foraminifera. However, because of its stratigraphic position, the El Fausto has been assigned to the Oligocene, and, for the same reasons as the Icotea, it is probably Middle Oligocene.

Correlation.—The upper part of the "Frontal sandstone" (Hedberg and Sass, 1937, p. 95) is in many places the basal part of the El Fausto. The latter is probably equivalent to the Upper or Middle Oligocene part of the Carbonera formation in the Colombian part of the basin and to the Bebedero formation of Mérida and Táchira. It thins eastward and grades laterally into the Icotea formation, which in turn is correlated with the La Victoria formation in the District of Miranda, Zulia.

BEBEDERO FORMATION (MIDDLE OLIGOCENE)

The name Bebedero is introduced at this time to designate a predominantly sandstone formation that crops out close by a wayside inn called "Bebedero Parado" near the Las Mesas end of the Seboruco-Las Mesas road in north-central Táchira. The type section is prominently exposed along a ridge about 250 meters southeast of the inn.

Lithology.—The formation is composed almost entirely of massive to well bedded, light gray to buff, fine and powdery to medium-grained, locally carbonaceous, plant-fossiliferous, ripple-marked sandstone. When fresh, the sandstone is generally hard but upon weathering becomes soft, friable, and sugary. Beds of gray, hard clay or shale, that never exceed a thickness of 2 meters, are present in very subordinate amounts.

The formation exhibits a fresh to slightly brackish-water type of sedimentation. The sandstones yield a simple tourmaline-zircon suite of heavy minerals.

Thickness.—Incomplete sections have not permitted accurate measurements but at the type section, the formation has a minimum estimated thickness of 100 meters (328 feet) and on the Río de Oro in northern Táchira the maximum thickness is estimated at 500 meters (1,640 feet).

Stratigraphic relationship.—The Bebedero lies unconformably on the Lobaterita formation and appears to be disconformable with the overlying Palmar formation.

Distribution.—The outcrop occurrence of the formation is limited to the northwest flank of the Mérida Andes in Táchira and southwestern Mérida. North of the Río Chama in central Mérida it is absent, either as a result of non-deposition or, more probably, overlap by the Palmar formation.

Age and paleontology.—On the basis of its stratigraphic position and lithology, the Bebedero formation has been assigned to the Middle Oligocene. No fossils have been found.

Correlation.—The Bebedero formation has a strong lithologic resemblance to the sandstones of the upper or Middle Oligocene part of the Carbonera formation. The Cúcuta fauna of the upper Carbonera also occurs on the Río Boconó of northern Barinas and its *Hannatoma* is found in the La Victoria formation of the District of Miranda. Other correlatives are the Icotea formation of northern Bolívar and Urdaneta Districts and the El Fausto formation of Perijá District.

MIOCENE

LA ROSA FORMATION (LOWER MIOCENE)

The name La Rosa formation derives from the village and oil field of La Rosa, the latter now a part of the Bolívar Coastal field in the District of Bolívar, eastern Zulia. It was first published by Hedberg and Sass (1937, pp. 99–100) and refers to a fossiliferous marine shale and sandstone formation that forms one of the principal Miocene divisions in the subsurface of the field.

Lithology.—The lowest member of the La Rosa formation is a brackish-water to marine, poorly consolidated sandstone known as the Santa Barbara sand. Much of it is highly argillaceous, and intercalations of gray or brown clay shale are common. Some of the gray clay shales contain spherulitic siderite. A thin lignitic deposit occurs locally at the very base and local thin limestones of great hardness are known in the southern part of the Bolívar Coastal field.

Above the Santa Barbara sand is a deeper-water, marine member composed chiefly of grayish green clay shale, interbedded with a few sandy shales and gray, thin, soft, commonly fossiliferous sandstones. On this the Intermediate sand rests in the northern end of the field but is wanting in the central and southern parts. This is overlain by a section of interbedded gray clay shales, sandy shales and soft sandstones, which is in turn followed by the soft, poorly consolidated sandstones and sands of the La Rosa sand member. The top of the La Rosa sand and the few feet of overlying sandy shale and gray clay shale are normally

a highly fossiliferous zone, which serves to mark the top of the formation. Carbonaceous material and local thin lignites occur in the section above the green clay shales. Toward the ancient shore line, brackish-water deposits commonly interfinger with or partially replace the normal marine sediments of this upper section. All three of the sand members are petroliferous.

The Miocene can be differentiated from the older formations by the influx of heavy minerals of metamorphic origin, such as kyanite, andalusite, and sillimanite. The Santa Barbara sand has been termed the Glaucophane zone because the occurrence of this mineral appears to be locally limited to that sand. The complete heavy-mineral suite of the La Rosa follows.

Abundant:	Ilmenite, leucoxene, zircon, tourmaline, muscovite, magnetite
Common:	Garnet, staurolite, epidote, glaucophane
Scarce:	Kyanite, andalusite
Rare:	Rutile, zoisite, clinozoisite, sillimanite, chlorite, chloritoid, titanite

The foregoing description of the lithology applies only to the Bolívar Coastal field, outside of which the various members mentioned can not be recognized. In the District of Urdaneta on the west side of the lake, the La Rosa in the subsurface consists almost entirely of greenish gray fossiliferous clay shale with a subordinate quantity of interbedded sandstones. In the Guanábana syncline outcrop area in the northern part of the District of Bolívar, the La Rosa sediments comprise dark to vari-colored clay shales with brown to tan and dark gray sandstone members, calcareous sandstones and sandy limestones. On the Cueva del Tigre anticline of the eastern part of the District of Miranda, the La Rosa is represented by sandy and silty clay shales which contain minor sandstone beds and very occasional impure sandy limestones. On the Quirós structure in southeastern Miranda the La Rosa is composed of gray, brown and black clay shales and silts with minor amounts of interbedded light to dark gray sandstones and a number of thin impure sandy limestones.

Thickness.—In the on-shore part of the La Rosa district of the Bolívar Coastal field, the La Rosa formation has a thickness of 180 to 250 meters (590 to 820 feet). It thins westward and in the District of Urdaneta varies from 0 to 125 meters (0 to 410 feet). It also thins in a short distance northward and much more slowly southward and southeastward, while northeastward it thickens to 1,006 meters (3,300 feet) on the Quirós structure.

Stratigraphic relationship.—The La Rosa formation rests unconformably on beds of the Middle Oligocene Icotea and La Victoria formations or, where these are missing, on Upper Eocene formations. Its upper boundary is everywhere conformable and gradational with the overlying Lagunillas formation. In fact, the southward and southeastward thinning and eventual disappearance of the La Rosa formation in the southern Tía Juana and northern Lagunillas off-shore areas of the Bolívar Coastal field, formerly thought due to erosion at an unconformity between the La Rosa and Lagunillas, is now known to be caused by an interfingering and lateral transition of the La Rosa with the lower part of the Lower Lagunillas sand, the basal member of the Lagunillas formation. The

sandier parts of the La Rosa make the transition from fossiliferous marine to brackish water deposition first, thus allowing the fossiliferous green clay shale member to extend farther south than the remainder of the formation. It is very possible that a similar lateral transition may take place in the District of Urdaneta toward the west. The La Rosa formation constitutes a marine tongue extending from Falcón into the essentially non-marine Miocene of the Maracaibo basin.

Distribution.—The La Rosa formation extends throughout the subsurface of the Ambrosio, La Rosa, Punta Benitez, Tia Juana, and northern Lagunillas divisions of the Bolívar Coastal field in the District of Bolívar, eastern Zulia, and across Lake Maracaibo to the subsurface of the District of Urdaneta. In northern and northeastern Bolívar and in southeastern and eastern Miranda the formation crops out on the surface, and it continues beyond the limits of the Maracaibo basin into the District of Buchivacoa in western Falcón.

Age and paleontology.—The first paleontologists who studied the La Rosa fauna were unable to decide whether it should be classified as Upper Oligocene or Lower Miocene. Floyd Hodson (1926) and Floyd and Helen Hodson and G. D. Harris (1927) called the Quirós outcrops Oligocene-Miocene, and the Buchivacoa outcrops were variously termed Oligocene or Oligocene-Miocene. Floyd and Helen Hodson (1931) called the Quirós outcrops Upper Oligocene and those in Buchivacoa Middle and Upper Oligocene. Haas and Hubman (1937, p. 126) reach no decision, saying

> Considerable controversy has arisen concerning the age of these fossiliferous deposits. Some workers consider the age to be Oligocene, while others prefer to class them as basal Miocene.

Halse (1937, pp. 178–79) assigns them to the Oligocene and Lower Miocene in Buchivacoa and continues:

> The subdivision into Agua Clara and San Luis refers particularly to the type locality in the neighborhood of Coro. It is not satisfactory in West Buchivacoa as there is no general natural division between these two particular formations. For this reason, the two groups are often classed together as the Agua Clara-San Luis. This nomenclature is adapted from Eastern Falcón where deposition was quite distinct from what it was in Buchivacoa at the same time Its convenience is that it gives a correlation in age without the introduction of new local terms.

It is apparent that Halse, and probably the Hodsons before him, confused the limestones in the Lower Miocene La Rosa formation with the Middle Oligocene orbitoidal limestones of the San Luis formation. Since the La Rosa fauna correlates with the Lower Miocene Upper Agua Clara fauna, it was considered necessary to use the hyphenated name.

Hoffmeister (1938, p. 117), after submitting detailed faunal evidence, correctly places the La Rosa formation in the Lower Miocene, and correlates it with the Quirós outcrops of Miranda and the Upper Agua Clara of central Falcón. He divides the La Rosa of the Bolívar Coastal field into a lower or *Cadulus* zone,

corresponding to the Santa Barbara sand, and an upper or *Microdrillia* zone, subdivided into a lower or *Bolivina* subzone, corresponding with the green clay shale member, and an upper or *Cibicides* subzone, representing the beds between the top of the green clay shale member and the base of the lower Lagunillas sand. The respective type fossils are *Cadulus* (*Gladiliopsis*) *dentalinus* Guppy, *Microdrillia trina* Mansfield, *Bolivina marginata* Cushman and *Cibicides americanus* (Cushman). It should be noted that *Cadulus dentalinus* also occurs in the *Microdrillia* zone, and that *Cibicides americanus* may be found in both the *Bolivina* subzone below and the *Lithophaga* zone of the Lagunillas formation above.

The *Cadulus* zone or Santa Barbara sand is ordinarily barren of foraminifera except sometimes for a few brackish-water arenaceous species. Large fossils are likewise rare or wanting except in the La Rosa and Ambrosio part of the Bolívar Coastal field, where the zone reaches its maximum thickness of about 30 meters (100 feet) and the following Mollusca have been recorded.

Nuculana (*Saccella*) *balboae* (Brown and Pilsbry)
Glycimeris canalis Pilsbry and Brown
Glycimeris trilobicostata Pilsbry and Brown
Crassinella bowdenensis (Dall)
Crenella diuturna Pilsbry and Johnson
Venericardia scabricostata Guppy
Lucina (*Bellucina*) *actina* (Dall)
Tellina (*Eurytellina*) *maoica* Maury
Corbula (*Caryocorbula*) *manzanillensis* Maury
Corbula (*Caryocorbula*) *oropendula* Olsson
Teinostoma (*Pseudorotella*) *caronensis* Mansfield
Cadulus (*Gladiliopsis*) *dentalinus* Guppy

All of the species in the foregoing list are also present in the overlying *Microdrillia* zone. In addition, there is an influx of new macrofossils.

Discoporella umbellata Defrance
Nellia oculata Busk
Nucula spp.
Nuculana spp.
Limopsis sp.
Arca (*Scapharca*) *cornellana* Hodson
Arca (*Scapharca*) *dariensis* Brown and Pilsbry
Arca (*Scapharca*) *mirandana* Hodson
Pecten (aff. *Aequipecten*) *quirosensis* Harris
Pecten (*Palliolum?*) *guppyi* Dall
Crassinella spp.
Chama quirosana Hodson
Lucina (*Lucinoma*) *riocanensis* (Maury)
Lucina (*Lucinisca*) *mirandana* Hodson
Montacuta sp.
Cardium (*Acanthocardia*) sp.
Cardium (*Condylocardia*) sp.
Cardium (*Laevicardium*) *serratum* Linné
Cardium (*Trachycardium*) sp.
Cardium (*Trigoniocardia*) *haitensis* Sowerby
Cardium (*Trigoniocardia*) sp.
Clementia dariena Conrad
Macrocallista maculata (Linné)
Pitar tryonianus (Gabb)
Pitar (*Pitarella*) *gatunensis* (Dall)
Pitar (*Hyphantosoma*) *carbaseus* (Guppy)
Chione (*Chione*) *paraguanensis* Hodson
Chione (*Lirophora*) *quirosensis queralana* Hodson
Dosinia delicatissima Brown and Pilsbry
Tellina (*Eurytellina*) *browni* Woodring
Macoma gatunensis Toula
Semele sayi Toula
Corbula (*Corbula*) *zuliana* Hodson
Corbula (*Caryocorbula*) *sericea* Dall
Corbula (*Bothrocorbula*) *guaiconensis* Maury
Corbula (*Tenuicorbula*) sp.
Tornatellaea sp.
Ringicula sp.
Acteocina sp.
Volvulella sp.
Scaphander nannus Woodring
Cylichna sp.
Cylichnella sp.
Terebra (*Oxymeris*) *wolfgangi* Toula
Terebra (*Acus*) spp.
Carinodrillia bocatoroensis (Olsson)
Carinodrillia elocata meta Woodring
Drillia chiriquiensis Olsson
Drillia fusiformis Gabb
Drillia scala Pilsbry and Johnson
Microdrillia trina Mansfield
Cymatosyrinx sp.
Polystira albida (Perry)
Polystira haitensis (Sowerby)
Scobinella morierei Cossmann
Conus floridanus var. *costaricensis* Olsson
Cancellaria sp.
Tribia losquemadica (Maury)
Oliva spp.
Olivella muticoides Gabb
Marginella (*Marginella*) *quirosensis* Hodson
Persicula (*Leptegouana*) *coniformis* (Sowerby)
Persicula (*Gibberula*) *trinitatensis* (Mansfield)
Hyalina (*Cysticus*) sp.
Vexillum bristoli Maury
Latirus sp.

Metula sp.
Tritiaria (*Antillophos*) *gatunensis* (Toula)
Hima (*Uzita*) *gurabensis* (Maury)
Hima (*Uzita*) spp.
Columbellopsis? sp.
Strombina caribaea Pilsbry and Johnson
Murex (*Murex*) *recurvirostris* Broderip
Typhis linguiferis Dall
Clava costaricana Olsson
Clava venada Maury
Biltium costatum Gabb
Biltium praeformatum Guppy
Modulus tamanensis Maury
Rissoina (*Phosinella*) *guppyi* Cossmann
Turritella berjadinensis cocoditana Hodson
Turritella caparonis Maury
Turritella cornellana Hodson
Turritella gatunensis Conrad
Turri.ella gilbertharrisi Hodson
Turritella guppyi Cossmann
Turritella guppyi morantensis Hodson
Turritella larensis Hodson
Turritella montañitensis Hodson
Turritella plebeia Say
Turritella venezuelana quirosana Hodson
Caecum sp.
Architectonica granulata Lamarck
Capulus sp.
Calyptraea sp.
Natica precanrena Hodson
Natica guppyana Toula
Liotia (*Liotia*) *strebla* Woodring
Liotia (*Arene*) *venusta* Woodring
Vitrinella spp.
Circulus spp.
Solariorbis sp.
Lissospira sp.
Teinostoma (*Pseudorotella*) spp.
Epitonium (*Nitidiscala*) sp.
Aclis sp.
Melanella gabbiana Pilsbry and Johnson
Eulima spp.
Pyramidella canaliculata Gabb
Pyramidella sp.
Syrnola sp.
Turbonilla contexta Pilsbry and Johnson
Turbonilla galeata Pilsbry and Johnson
Turbonilla (*Strioturbonilla*) *dominicensis* Gabb
Turbonilla santodomingensis Gabb
Turbonilla (*Chemnitzia*) spp.
Turbonilla (*Pyrgiscus*) spp.
Odostomia sp.
Dentalium bocasensis Olsson
Laevidentalium spp.
Cadulus (*Gladiliopsis*) *dentalinus* Guppy
Creseis sp.

The foregoing macrofossils from the La Rosa formation in the Bolívar Coastal field were mostly identified by Hoffmeister with some additions and corrections by Dusenbury. They indicate a shallow, warm-water, marine habitat of Lower Miocene (Burdigalian) age. Many of the species were originally described from the Bowden formation (Middle Miocene) of Jamaica, the Cercado and Gurabo formations (Lower and Middle Miocene) of the Dominican Republic, the Gatún formation (Lower and Middle Miocene) of Panamá and Costa Rica, and the Machapoorie, Manzanilla, and Brasso formations (Lower and Middle Miocene) of Trinidad. In the opinion of A. A. Olsson the fauna can be correlated with that from the Lower Miocene Cercado formation of the Dominican Republic.

For the prolific La Rosa macrofauna of the outcrop area in the districts of Miranda and Buchivacoa, the reader may refer to the three papers published by the Hodsons and mentioned at the beginning of this discussion.

The following genera of foraminifera are commonest in the La Rosa formation of the Bolívar Coastal field.

Ammobaculites
Amphistegina
Bolivina
Buliminella
Cassidulina
Cibicides
Discorbis
Elphidium
Eponides
Globigerina
Globigerinoides
Haplophragmoides
Miogypsina
Nonion
Nonionella
Peneroplis
Pyrgo
Quinqueloculina
Robulus
Rotalia
Sorites
Spiroloculina
Textularia
Triloculina
Trochammina
Uvigerina

All of these occur in the *Bolivina* subzone, but *Bolivina* itself, *Buliminella*, and *Uvigerina* have never been found in the overlying, *Cibicides* subzone. *Amphistegina chipolensis* Cushman and Ponton, *Cassidulina chipolensis* Cushman and Ponton, and *Elphidium chipolense* (Cushman) serve to correlate the La Rosa with the Chipola formation (Lower Miocene) of Florida.

Correlation.—The names Upper La Rosa and Lower La Rosa (Haas and Hubman, 1937, pp. 119–27) are now considered obsolete, all the major oil companies having agreed to call the former the Lagunillas formation and the latter the La Rosa formation. This same course is followed in the present paper.

The Río Chiquito formation of Garner (1926, p. 682) refers to a section of La Rosa exposed along the Río Chiquito in the northeastern part of the District of Bolívar. The lower part of the Quirós formation of Garner (1926, p. 682) represents the La Rosa outcrops on the Quirós structure in the southeastern part of the District of Miranda. The "El Mene marine series" of Williston and Nichols (1928, p. 449) is the local name once applied to the La Rosa formation in the El Mene de Mauroa oil field in the western part of the District of Buchivacoa in western Falcón. Farther east, in the District of Democracia, the correlative of the Santa Barbara sand combined with the *Bolivina* subzone of the La Rosa is the Lower Miocene Upper Agua Clara formation (Garner, 1926, p. 681; Liddle, 1928, pp. 260–69), while the correlative of the *Cibicides* subzone is the Lower Miocene Cerro Pelado formation (Liddle, 1928, pp. 272–78). The Lower Agua Clara is Upper Oligocene and does not appear to have any equivalent in the Maracaibo basin. The Agua Clara and San Luis formations of Halse (1937, pp. 178–79) can be assigned to the La Rosa in western Buchivacoa and to the Cerro Pelado and Upper Agua Clara in central and eastern Buchivacoa.

Southward and probably westward in the Maracaibo basin there is a lateral transition from the marine facies of the La Rosa formation into the brackish- to fresh-water facies of the lower part of the Lower Lagunillas sand member of the Lagunillas formation. Still farther south the La Rosa correlatives are the unfossiliferous lower part of the Palmar formation of Trujillo, Mérida, and Táchira and the lower part of the León shale (Notestein, Hubman, and Bowler, 1944, pp. 1201–03) in the District of Colón and the Barco region.

LAGUNILLAS FORMATION (LOWER AND MIDDLE MIOCENE)

The name Lagunillas formation refers to one of the major Miocene subsurface divisions of the Bolívar Coastal field and is derived from the village and oil field of Lagunillas, located on the eastern shore of Lake Maracaibo in the District of Bolívar, eastern Zulia. The Lagunillas oil field expanded until it coalesced with its neighbors, and now forms part of the Bolívar Coastal field. The Miocene Lagunillas formation of Hedberg and Sass (1937, pp. 100–02) should not be confused with the questionably Triassic Lagunillas conglomerate of Sievers (1888, pp. 8–16) in central Mérida. This term of Sievers has been rather unsatisfactory for the reasons mentioned in the discussion of the La Quinta formation and has generally been relegated to oblivion.

Lithology.—The Lagunillas formation is the deposition resulting from rapid changes from brackish-water to non-marine to marine to fresh-water sedimentation. The formation as a whole is composed chiefly of interbedded shales, clays, sands, poorly consolidated sandstones, and some lignites.

The basal 100 to 150 meters (328 to 492 feet) of the formation is known as the Lower Lagunillas sand, a member which is found throughout the Bolívar Coastal field. The unconsolidated sands and poorly consolidated sandstones of this member are commonly porous and in many places aquiferous or petroliferous. They form the reservoir for much of the heavy oil produced in the Bolívar Coastal field. Interstratified with the sands and sandstones are shales and clay shales in various shades of light to dark gray, greenish gray, brownish gray and, rarely, purplish gray. These shales and clay shales commonly contain thin laminations of sand which form planes of weakness and create a false impression that the shales are extremely fissile. Carbonaceous fragments are commonly found in the clay shales but lignites are rare and of very local extent. The top of the Lower Lagunillas sand is usually fixed by the first appearance of shales with sand laminations, the base by the first appearance of the La Rosa marine fauna.

On top of the Lower Lagunillas sand lies a thin series of bleached and mottled clays, sands, lignites and black carbonaceous sticky clays which probably originated as swamp muck. In the Lagunillas area this zone thickens, especially the sands, which locally become predominant and are called the Upper Lagunillas sand.

A widespread marine invasion of brief duration followed and beds of fossiliferous gray shale and sandy shale were deposited. In the Lagunillas and Tia Juana on-shore and near-shore areas these fossiliferous shales are interstratified with non-fossiliferous glauconitic beds, which become very sandy in the Lagunillas on-shore area. Here they reach a maximum thickness of 40 meters (131 feet) and have been termed the Laguna sand.

The upper half of the Lagunillas formation is composed of interbedded clays, clay shales, sandy clays and soft, poorly consolidated sandstones. Normally, the clays are gray to brown in color, but they are commonly bleached white or mottled red, blue, green, and yellow. Lignites from a few inches to 5 feet thick are commonly encountered. Beds of siderite are rare, but spherules of siderite less than a millimeter in diameter are found in great abundance scattered throughout the white and pale gray bleached clays. Sands and sandstones increase toward the top and are petroliferous in parts of the Lagunillas and Bachaquero districts. This part of the section has been named the Bachaquero sand.

The heavy-mineral suite of the Lagunillas formation is ordinarily undifferentiated from that of the La Rosa formation above the Santa Barbara sand. However, in a few places grains of horneblende have been noted in the Lagunillas, whereas this mineral has not been observed in the La Rosa.

Thickness.—In the type locality the Lagunillas formation has a thickness of approximately 300 meters (984 feet). The maximum measured in the Bolívar

Coastal field is in the Tía Juana district, where 450 meters (1,480 feet) are present. The formation thickens toward the west, and in the central part of the District of Urdaneta on the west side of the lake, reaches a total of about 900 meters (2,952 feet). It thins northward and wedges out a short distance north of Icotea well No. 1. Progressive thinning is also noted eastward from the Bolívar Coastal field and southward from Tía Juana. The thickness of the Lagunillas is greatly diminished in the Bachaquero district and the formation is absent in the Mene Grande area. Northeast of the Bolívar Coastal field the Lagunillas formation crops out in northeastern Bolívar and southeastern Miranda. A thickness of approximately 152 meters (500 feet) was estimated on the Quirós structure in the latter area.

Distribution.—The Lagunillas formation crops out only in northeastern Bolívar and southeastern Miranda in the eastern part of Zulia. It is met in the subsurface throughout the Bolívar Coastal area and across the lake in the eastern and central parts of the districts of Urdaneta, Maracaibo, and Mara.

Stratigraphic relationship.—The Lagunillas formation conformably rests on the La Rosa formation as a rule, but toward the margins of the depositional area of the latter the lower part of the Lower Lagunillas sand interfingers with the marine beds of the La Rosa and laterally replaces them with brackish-water sediments. Westward the Lagunillas formation grades laterally into the Los Ranchos formation. The Lagunillas appears to be conformable with the overlying La Puerta formation.

Age and paleontology.—In the offshore area of the La Rosa and northern Punta Benitez districts of the Bolívar Coastal field, a thin fossiliferous bed in the lower part of the Lower Lagunillas sand was cored in a number of wells. This area is in the center of the La Rosa depositional basin and a normal thickness of La Rosa was penetrated below, so that there is no question of the type of interfingering found around the margins of the La Rosa depositional basin. The fossil bed is nowhere more than 2 feet thick and occurs 15 to 24 meters (50–80 feet) above the La Rosa-Lagunillas contact. The Mollusca and Foraminifera belong to the fauna found in the *Cibicides* subzone of the La Rosa formation and are likewise of Lower Miocene age. The commonest macrofossil is *Crenella diuturna* Pilsbry and Johnson, which occurs throughout the La Rosa. This fossil bed, which has been named the *Crenella* zone, provides evidence additional to the aforementioned interfingering that the Lower Lagunillas sand is Lower Miocene in age. Outside of the *Crenella* zone, only rare arenaceous brackish-water Foraminifera, brackish-water Ostracoda, and a few fish teeth and bones have been found in the Lower Lagunillas sand. However, the contact between the Lower and Middle Miocene has been tentatively placed at the top of the Lower Lagunillas sand.

The ensuing non-marine deposition, which includes the Upper Lagunillas sand, is unfossiliferous except for carbonized plant fragments. Still higher are the fossilferous marine beds of the *Lithophaga* zone. In the Tía Juana district of the Bolívar Coastal field this zone can be divided into an upper or *Turritella* sub-

zone and a lower or *Anomia* subzone with a 30-foot barren interval between. Although the *Lithophaga* zone often diminishes to a few feet in thickness, it is continuous throughout the Bolívar Coastal area and provides a valuable marker for purposes of correlation. According to Hoffmeister (1938, p. 111), the name *Lithophaga* zone is actually a misnomer, the identification of the locally abundant type fossil having later been corrected to *Julia* sp. However, the old name has so far been proved to be too well intrenched to permit the required change.

Except for a few minor changes the following list of the macrofossils of the *Lithophaga* zone is taken from Hoffmeister (1938, p. 112).

Arca (*Scapharca*) *cornellana* Hodson
Arca (*Scapharca*) *mirandana* Hodson
Anomia indecisa Dall
Julia sp.
Crassinella bowdenensis (Dall)
Lucina (*Lucinisca*) sp.
Macrocallista maculata (Linné)
Chione (*Chione*) *walli* Guppy
Tellina (*Eurytellina*) *maoica* Maury
Siliqua subaequalis Gabb
Corbula (*Corbula*) *zuliana* Hodson
Corbula (*Caryocorbula*) *oropendula* Olsson
Corbula (*Caryocorbula*) sp.
Drillia scala Pilsbry and Johnson
Bittium praeformatum Guppy
Turritella altilira mirandana Hodson
Turritella berjadinensis Hodson
Turritella cornellana Hodson
Turritella gatunensis Conrad
Vitrinella sp.
Circulus sp.
Turbonilla (*Chemnitzia*) sp.
Turbonilla (*Strioturbonilla*) *dominicensis* Gabb
Turbonilla (*Pyrgiscus*) sp.
Turbonilla (*Visma*) *turritelloides* Gabb

The following genera of Foraminifera are found in the *Lithophaga* zone.

Ammobaculites
Bolivina
Buliminella
Cibicides
Elphidium
Eponides
Globigerina
Globigerinoides
Nonion
Quinqueloculina
Reussella
Rotalia
Textularia

There are certain species of *Bolivina* and *Reussella* which indicate a Middle Miocene age, and the fauna as a whole is sufficiently different from that of the underlying La Rosa to warrant assignment to the lower Middle Miocene.

Correlation.—Locally the lower part of the basal member of the Lagunillas interdigitates with the La Rosa formation. Westward the entire Lagunillas grades laterally into the Los Ranchos formation of Liddle (1928, pp. 308–12). Southward the Lagunillas formation is correlated with the upper part of the Palmar formation in Trujillo, Mérida and Táchira; the upper part of the León shale of Notestein, Hubman, and Bowler (1944, pp. 1201–03) in the District of Colón and the Barco Concession; and the lower part of the Parángula formation of Mackenzie (1937, pp. 264–65) in the State of Barinas.

The Upper La Rosa of Haas and Hubman (1937, pp. 119–21) is an obsolete synonym for the Lagunillas formation. The Lagunillas exposures on the Quirós structure in southeastern Miranda form the upper part of the Quirós formation of Garner (1926, p. 682). In western Buchivacoa, Falcón, the Lagunillas equivalents have been called the "El Mene carbonaceous series" by Williston and Nichols (1928, p. 449) and the Lower La Puerta by Gonzalez de Juana (1938, pp. 130–31). In eastern Buchivacoa the correlative of the Lagunillas is the Ojo de Agua beds of

Liddle (1928, pp. 318–19, correlation chart). The Lower Miocene part of the Lagunillas formation correlates with the Cerro Pelado formation of the District of Democracia (Liddle, 1928, pp. 272–78), while the Middle Miocene part is the equivalent of the combined Socorro (Liddle, 1928, pp. 286–88) and Urumaco (Garner, 1926, p. 683) formations in the same region.

PALMAR FORMATION (LOWER AND MIDDLE MIOCENE)

The name Palmar derives from the village of Mesa Palmar in southern Trujillo. It is introduced at this time to designate a series of interbedded shales, sandstones, and clays which crop out along the Río Buena Vista just below the village. The base of the formation is 700 meters (2,297 feet) downstream from the crossing of the Monte Carmelo-Las Pavas trail and the top is 1,050 meters (3,445 feet) farther downstream.

Lithology.—In Trujillo and northern Mérida the Palmar formation consists mainly of clays, sandstones and shales, which are massively interbedded with each other in approximately equal proportions. The clays are mottled dull red, olive-brown, and dark green and are locally sandy, indurated, carbonaceous, and plant-fossiliferous. They also contain crustacean burrows refilled with sand. The sandstones are light gray, friable, fine-grained to locally conglomeratic, commonly poorly sorted, and locally micaceous and carbonaceous. The shales are dark gray to black, hard, locally carbonaceous and fossiliferous. Some thin beds of lignitic coal and hard siltstone are present here and there. In southern Mérida and Táchira the clays and coal beds are less prominent or absent.

The mineral yield of the formation shows staurolite, tourmaline, zircon, and muscovite to be common, while epidote, anatase, zoisite, chlorite, and chloritoid are sporadic.

The type of sedimentation is brackish-water to shallow-marine.

Thickness.—At the type locality in southwestern Trujillo the Palmar formation has a thickness of 570 meters (1,870 feet). Southward, on the Caño Tigre in west central Mérida, it is 590 meters (1,935 feet). This rather uniform thickness may be exceeded in southwestern Mérida and Táchira.

Stratigraphic relationship.—In southwestern Trujillo and west-central Mérida, the Palmar rests unconformably on the Paují and Lobaterita formations. Southward, in southwestern Mérida and northern Táchira, it is disconformable with the underlying Bebedero formation.

The Isnotú overlies the Palmar formation conformably.

Distribution.—The outcrop occurrence of the formation extends from the Río Buena Vista in southwestern Trujillo southward along the Andean front to the Colombian border. Northward from the Río Buena Vista, it is overlapped by the Isnotú formation.

Age and paleontology.—The age of the Palmar formation is Lower and Middle Miocene. A Middle Miocene fauna has been recovered from its upper part, but no diagnostic fossils have been found in the middle and lower parts.

Several typical assemblages are here listed.

1. Río Buena Vista, southwest Trujillo. From black shale and siltstone 170 meters (558 feet) below the top of the formation. Collected by P. P. Wolcott, identified by V. D. Winkler.

Tellina sp., cf. *T. dariena* Conrad
Chione spp.
Macoma spp.
Nuculana sp.
Chione sp., cf. *C. angellana* Spieker
Tellina sp.
Venericardia sp.
Dosinia sp.
Cardium sp.
Tagelus sp., cf. *T. cebus* Olsson
Chione sp., cf. *C. cancellata* (Linné)
Nucula sp.
Sanguinolaria sp., cf. *S. alouatta* Olsson

2. Río Pajita, northern Táchira. From dark gray, silty shale in upper part of formation.

Chione sp., cf. *C. cancellata* (Linné)
Semele sp.
Murataea sp.
Diplodonta sp.
Pitar sp.
Mactra sp.
Lucina (*Lucinisca*) sp.
Pecten sp.
Capulus sp.
Abra triangulata Dall
Montacuta sp.
Tellina sp.
Lucina sp.
Sanguinolaria sp.
Arca sp.
Labiosa sp., cf. *L. undulata* mirandana Hodson

Kehrer (1938, p. 46) lists the following fossils collected from light gray sandy shales which crop out beneath the bridge south of Uracá on Río Lobaterita in northwest Táchira. This zone is in the upper part of the Palmar formation. Identifications are by Maury.

Mitra henekeni Sowerby
Pitaria cf. *sayana* Conrad
Macrocallista (*Chionella*) cf. *maculata* Linnaeus
Arca sp.
Semele cf. *sayi* Toula
Turris albida Perry
Turritella sp.
Conus cf. *dalli* Toula
Terebra cf. *wolfgangi* Toula
Natica (*Stigmaulax*) *guppyana* Toula
Olivella sp.
Drillia cf. *vaningeni* Brown and Pilsbry
Arca cf. *inaequilateralis* Guppy
Pteria cf. *inornata* Gabb
Pinna sp.
Pecten cf. *laevicostatus* Toula
Cardium sp.
Corbula (*Aloidis*) *vieta?* Guppy
Corals
Crab claws

Borger has identified the following microfauna from the same locality in the Río Lobaterita.

Elphidium sp.
Elphidium cf. *chipolense* (Cushman)
Cibicides spp.
Eponides sp.
Robulus sp.
Cassidulina chipolensis Cushman and Ponton
Microgastropods
Micropelecypoda
Ostracoda

Common Foraminifera from other localities include species of *Siphogenerina*, *Ammobaculites*, *Haplophragmoides*, *Trochammina*, *Quinqueloculina*, *Nodosaria*, *Textularia*, and *Spiroplectammina*.

The macrofossils from the Río Lobaterita locality are correlated rather well with the fauna listed from the Middle Miocene Urumaco formation, District of Democracia, Falcón, by Liddle (1928, pp. 300–01). This evidence is considered of greater weight than the presence of *Cassidulina chipolensis* Cushman and Ponton, which has always been considered indicative of the Lower Miocene but may well range upward into the Middle Miocene.

Correlation.—The Palmar formation is the exact equivalent of the basal part

of the Betijoque beds of Liddle (1928, pp. 279–80) in which that author mentions the presence of "Lower Miocene" fossils. The Palmar can be correlated with the León formation of Notestein, Hubman, and Bowler (1944, pp. 1201–03) in the District of Colón and the Barco Concession. In fact, it is debatable whether the Río Lobaterita section should be placed in the Palmar or the León. The lower part of the Palmar is equivalent to the La Rosa formation and the upper part to the Lagunillas formation of the Bolívar Coastal field. The Palmar probably should be correlated with the lower part of the Parángula formation of Mackenzie (1937, pp. 264–65) in Barinas.

LEÓN FORMATION (LOWER AND MIDDLE MIOCENE)

The name León formation has been employed by Notestein, Hubman, and Bowler (1944, pp. 1201–03) to replace the term "Upper Shale horizon" (Liddle, 1928, pp. 312–14), which is unsatisfactory because of its non-geographic derivation. The type section is along the Quebrada León, a tributary of the Río Zulia on the east flank of the Petrolea anticline in the southeast part of the Barco Concession, Colombia. It is composed almost entirely of gray and greenish gray shales, but there are a few intercalated beds of gray or buff sandstone with carbonaceous laminae. A series of buff sandstones with a maximum thickness of 28 meters (91 feet) is located slightly above the middle of the formation and has been called the Machete sandstone member. The thickness of the entire León formation ranges from 350 meters (1,148 feet) in the Tibú-Socuavo area to 785 meters (2,575 feet) in the type section.

The León formation lies with probable disconformity on the Carbonera and with probable conformity beneath the Guayabo group. Notestein *et al.* report the foraminiferal genera *Ammobaculites*, *Haplophragmoides*, *Flabellammina*, *Spiroplectammina*, *Quinqueloculina*, and *Trochammina* from near the León-Carbonera contact in the Río Nuevo area. This microfauna is probably reworked, the third and fourth of the genera cited having been derived from the Cretaceous, the others from the Eocene. The section containing a Middle Miocene macrofauna between Uracá and Estación Táchira on the Río Lobaterita is included by Notestein *et al.* in their León formation, but has been discussed in the preceding paragraphs as part of the Palmar formation. Since the León is thought to correlate perfectly with the Palmar, its age is likewise considered as Lower and Middle Miocene.

LOS RANCHOS FORMATION (LOWER AND MIDDLE MIOCENE)

The name Los Ranchos was introduced by Liddle (1928, p. 308) to designate a predominantly clay and sandstone formation that crops out at the settlement of Los Ranchos, about 25 kilometers southwest from La Villa del Rosario in the District of Perijá, Zulia.

Lithology.—The outcrops of the formation are composed mainly of tan to light brown, rather friable, fairly well bedded, fine to coarse sandstone. Pebble beds and ferruginous sandstone concretions are common. Where penetrated in

the exploratory wells Neopig No. 1 (Richmond Petroleum Company) and Macoa No. 1 (Creole Petroleum Corporation), the formation is composed largely of light green and light gray clays that are occasionally mottled red. In the Manuelote syncline coarse conglomerates are common, especially along the western limb.

The mineral yield shows leucoxene, zircon, tourmaline, rutile, and staurolite with subordinate kyanite and andalusite. Garnet and epidote are present in places near the base.

The type of sedimentation is fresh- to brackish-water.

Thickness.—Sections of the Los Ranchos formation drilled in exploratory wells in the vicinity of the type area indicate a thickness of approximately 1,300 meters (4,207 feet). The formation thins toward the north and south, thickens again in the Manuelote syncline.

Stratigraphic relationship.—In the type area the Los Ranchos is overlain conformably by the La Villa formation and is unconformable with the subjacent El Fausto formation. Northward, in the Manuelote syncline, it rests unconformably on the Las Flores and older formations. The Los Ranchos formation passes laterally eastward into the Lagunillas formation.

Distribution.—The outcrop occurrence of the formation includes the type area east of the Sierra de Perijá front in the District of Perijá, another area immediately east of the Los Ocho fault between the Río Cachirí and the Río Guasare in the District of Mara, and a third area along the axis of the Manuelote syncline farther west in Mara. In the District of Maracaibo the Los Ranchos has been overlapped by the La Villa.

Age and paleontology.—The Los Ranchos formation has been assigned to the Lower and Middle Miocene through correlation with the Lagunillas formation. Fossils are exceptionally rare. The brackish-water Foraminifera, *Miliammina fusca* (Brady) and *Rotalia beccarii* (Linné) have been encountered.

Correlation.—The Los Ranchos grades laterally eastward into the Lagunillas formation. It is probably equivalent to the upper part of the Palmar formation in Trujillo, Mérida and Táchira, and the upper part of the León formation in the Barco Concession and the District of Colón.

In the type area the Los Ranchos forms the lower half of the Arimpia formation of Garner (1926, p. 682). Arimpia is still occasionally used as a group name to include the Los Ranchos and La Villa formations. The type locality is the vicinity of the village of Arimpia, which is located on the outcrop of the La Villa formation just east of the Los Ranchos contact.

In the Manuelote syncline the Los Ranchos has been called the Los Melones formation by Garner (1926, p. 681). The type locality is at a bluff cut by the Río Guasare at the village of Los Melones in the southwest part of the District of Paez. Here the clays, mottled clays and soft sandstones of the Los Ranchos lie unconformably beneath the Cerro Vigía boulder conglomerate.

LA PUERTA FORMATION (MIDDLE MIOCENE)

The name La Puerta was first published by Hodson (1926, p. 4) and later

used by Liddle (1928, pp. 319–20), Halse (1937, p. 177) and Gonzalez de Juana (1938, pp. 130–31) to designate a predominantly claystone and sandstone formation which crops out at Cerro de la Puerta, 15 kilometers southeast of Dabajuro in the District of Buchivacoa, State of Falcón. The formation typically includes an upper and a lower member, separated by an unconformity. In the Bolívar Coastal field the name is restricted to the equivalent of the Upper La Puerta of the type locality and this restriction should be adopted everywhere.

Lithology.—In the Bolívar Coastal field the La Puerta formation is composed of bright blue, yellow, green and red, mottled claystones; yellow-brown and red, mottled siltstones; brown siltstones, and light greenish gray, fine to locally coarse grained, friable, massive sandstones. Southward, where the formation is thicker, the basal part contains non-mottled light-colored siltstones and claystones, light green shaly sandstones, and gray silty shales. Marine intercalations are locally present. The absence of lignite differentiates the La Puerta from the underlying Lagunillas formation.

The formation yields a typical Miocene heavy mineral suite. Zircon and tourmaline are common; ilmenite, rutile, anatase, brookite, and leucoxene are persistent and staurolite, kyanite, and andalusite are commonly present.

The fresh to brackish-water sediments of the La Puerta in the Bolívar Coastal field grade westward into typically non-marine sediments. Eastward they grade into dominantly marine sediments in northeastern Zulia and western Falcón.

Thickness.—The thickness of the La Puerta formation varies from 170 to 700 meters (558 to 2,297 feet). Increases in thickness are noted from north to south in the Bolívar Coastal field and eastward into Falcón.

Stratigraphic relationship.—In the Bolívar Coastal field the La Puerta is transitional with the underlying Lagunillas formation. Where the latter is not present, an unconformable relationship exists with older sediments. In Buchivacoa the restricted La Puerta rests unconformably on the Lagunillas equivalent. The relationship with the overlying El Milagro formation appears to be unconformable.

Distribution.—Sediments referred to as the La Puerta formation are restricted to the Districts of Bolívar and Miranda in northeastern Zulia and the District of Buchivacoa in western Falcón.

Age and Paleontology.—Only reworked Foraminifera and a few brackish-water fossils have been found in the La Puerta formation in the Bolívar Coastal field area. From the laterally equivalent fossiliferous marine beds in Falcón, however, an upper Middle Miocene age has been established.

Correlation.—The La Puerta is the equivalent of the La Villa formation of western Zulia and the Isnotú formation in the southeastern part of the basin. It is believed to be correlative with the lower part of the Guayabo group in the District of Colón and in the Barco Concession in eastern Colombia. In western Buchivacoa it has been called the Upper La Puerta by Gonzalez de Juana (*loc. cit.*) and the "El Mene sandstone series" by Williston and Nichols (1928, p. 449). Eastward in Falcón the La Puerta may be correlated with the marine La Vela formation (Liddle, 1928, pp. 314–26).

ISONTÚ FORMATION (MIDDLE MIOCENE)

The name Isnotú is introduced at this time to define a predominantly clay and sandstone formation which crops out at and west of the village of Isnotú on the road between Motatán and Betijoque in the west-central part of the State of Trujillo.

Lithology.—The formation is composed principally of interbedded clays and sandstones, with subordinate amounts of clay shale, coal, and conglomerate. The clays, which comprise about 65 per cent of the formation, are massive, locally sandy, soft and light gray in color. Mottling is common with red, purple, and yellow predominating. Some of the clays are carbonaceous and plant-fossiliferous. The sandstones, which occur in beds up to 2 to 3 meters in thickness, are white to light gray, fine-grained to finely conglomeratic, locally micaceous and ripple-marked. Embedded pellets of white clay are common. Some sandstones are light to dark gray and greenish gray, laminated, fine-grained to clayey, carbonaceous and plant-fossiliferous. Subordinate amounts of soft, gray, locally laminated, micaceous and plant-fossiliferous clay shales are present. Thin beds of lignitic coal and massive beds of poorly sorted conglomerate are sparingly present. The conglomerates occur mostly in Mérida and Táchira, and in this same region the upper part of the formation contains interbedded sandstones and dark gray to black shales which are locally fossiliferous.

The formation yields a mineral suite comprising tourmaline, zircon, staurolite, andalusite, sillimanite, zoisite, kyanite, biotite, muscovite, and glaucophane. The paucity of epidote and the presence of mottling and white sandstone differentiate this formation from the overlying Betijoque.

The bulk of the formation was deposited in fresh to brackish water with short local marine incursions.

Thickness.—The thickness of the Isnotú formation remains fairly constant at about 1,100 meters (3,609 feet) throughout the outcrop belt. It thins basinward northwest.

Stratigraphic relationship.—From the Río Buena Vista in southern Trujillo southwestward to the Colombian border, the Isnotú appears to overlie the Palmar formation conformably. On the north, in Trujillo and the District of Sucre, it overlaps the Palmar formation and rests unconformably on older sediments.

The Isnotú is overlain conformably, and locally overlapped, by the Betijoque formation.

Distribution.—The outcrops of the formation occupy a narrow, fairly continuous belt along the northwest front of the Mérida Andes through the States of Trujillo, Mérida and Táchira. In the subsurface the Isnotú passes northward through the District of Sucre and grades into the La Puerta in the District of Bolívar.

Age and paleontology.—The Isnotú formation has been assigned to the upper part of the Middle Miocene on the basis of stratigraphic position and paleontology. Fossils are meagerly present. The following micofauna from a shale

member of the formation in the Quebrada Blanca, a branch of the Río Omuquena in north central Táchira, has been identified by Borger.

Globigerina sp.
Ammobaculites sp.
Rotalia beccarii (Linné) var.
Textularia sp.
Eponides sp.
Ostracoda

The same shale contains the following macrofossils, which have been identified by Winkler.

Terebra sp.
Nucula sp.
Yoldia sp.
Tellina sp.
Drillia sp.
Corbula sp.
Polinices sp.
Oliva or *Ancillaria* sp.
Crab fragments

The foregoing macrofauna resembles that found in the Upper Miocene La ica formation of eastern Venezuela. The microfauna, however, appears to be Middle Miocene in age.

Correlation.—The Isnotú formation is the equivalent of the La Villa formation of western Zulia and the La Puerta formation of the Bolívar Coastal field. It correlates with the lower part of the Guayabo group in the District of Colón and the Barco Concession area, and with the upper part of the Parángula formation of Mackenzie (1937, pp. 264–65) in Barinas. It is the same as the Lower Maracaibo series of Tash (1937, p. 163) in the Mene Grande region and the middle part of the Betijoque beds of Liddle (1928, pp. 279–80) in Trujillo.

LA VILLA FORMATION (MIDDLE MIOCENE)

The name La Villa formation has been used by Garner (1926, p. 681) and Liddle (1928, pp. 326–33) to designate a predominantly claystone and sandstone formation that crops out near the village of La Villa del Rosario in the north-central part of the District of Perijá, Zulia. The type section extends from a point about 2 kilometers east of the village, where the formation disappears beneath alluvium, westward about 9 kilometers to a point just west of the village of Arimpia, where the base is in contact with the underlying Los Ranchos formation.

Lithology.—The La Villa formation is composed typically of red and light gray to greenish gray, mottled claystones and massive, poorly sorted, red, white and purple sandstones. White mottling is common in the darker sandstones. Poor stratification, rapid facies changes and poor sorting are characteristic. Thin lenses of clay ironstone are abundant and the top of the formation commonly consists of red lateritic conglomerate with iron oxide pebbles. The heavy-mineral assemblage is the same as that of the La Puerta formation.

The type of sedimentation suggests fresh to occasional brackish-water deposits, with the addition of subaerial alluvial fans, cones, and outwash-plain deposits along the mountain front.

Thickness.—In the type area the thickness of the formation varies from 900 to 1,200 meters (2,950 to 3,940 feet). In other localities the La Villa may be present as a thin veneer only. There is a regional thickening from north to south.

Stratigraphic relationship.—In the type area the La Villa appears to be conformable with the underlying Los Ranchos formation, but in other areas it overlaps the Los Ranchos and is unconformable with older formations. In the districts of Paez, Mara, and Maracaibo it is unconformable with the overlying El Milagro formation. The latter was deposited only after a long period of subaerial exposure of the La Villa, during which the red lateritic conglomerate cap was formed by weathering. Farther south the La Villa in the District of Perija passes laterally into the lower part of the Guayabo group in the District of Colón.

Distribution.—Sediments of the La Villa are recognized throughout the western part of the Maracaibo basin, from the District of Paez in the north to the District of Colón in the south.

Age and paleontology.—The formation is almost barren of fossils. It contains some reworked Foraminifera and a few indigenous brackish-water Foraminifera of no diagnostic value. It has been assigned to the upper Middle Miocene in view of its stratigraphic position and lithologic correlation.

Correlation.—The La Villa formation is considered equivalent to the La Puerta of northeastern Zulia and western Falcón, the Isnotú of Trujillo, Mérida and Táchira, and the lower part of the Guayabo group in the District of Colón and the Barco Concession. It forms the upper part of the Arimpia formation of Garner (1926, p. 682) in northern Perijá and is synonymous with the Cerro Cochino formation of Garner (1926, p. 682) in the District of Mara. Cerro Cochino is the high hill at the south end of the Kilometer-24 structure in southern Mara.

GUAYABO GROUP (MIDDLE AND UPPER MIOCENE)

The Guayabo was originally described as a formation by Liddle (1928, pp. 333–39), but Notestein, Hubman, and Bowler (1944, pp. 1203–04) have raised it to group status without, however, dividing it into its component formations. It takes its name from Cerro Guayabo in the southern part of the District of Colón, southwestern Zulia. Liddle has apparently included some of his "Upper Shale horizon" (León formation) in the base of his Guayabo, as he himself admits might be possible. Eliminating this, there is left about 305 meters (1,000 feet) of mottled red and white clays and sandstones, with which are intercalated some varicolored clays, grayish buff sandstones, and ferruginous conglomerates; and a series of overlying conglomeratic sandstones and conglomerates, interbedded with light gray clays and of unknown thickness. The lower of these two formations, according to Liddle, can be traced northward into the La Villa formation in northern Colón and Perijá; the upper becomes the Onia beds of Hedberg and Sass (1937, pp. 106–07) in the subsurface of Perijá and Urdaneta.

In the Barco Concession on Quebrada León, Notestein *et al.* have measured 803 meters (2,635 feet) of the lower or mottled formation, erroneously correlating it with the El Fausto and Los Ranchos. The tremendously thick section of "Guayabo" (2,640 meters or 8,661 feet) reported in the Cúcuta area by these

authors obviously includes formations older than the Guayabo of Colón, Táchira, and Quebrada León. The La Cira fauna found by Olsson in its basal member is everywhere of uppermost Oligocene (Aquitanian) age, while the Guayabo of Táchira rests on the Palmar or León formation, which contains a large Middle Miocene fauna in its upper part. The "Guayabo" of Cucutá presumably includes the León and a still lower Aquitanian formation that is missing at the north but, according to Olsson, is widespread on the south.

The Guayabo of Táchira (Kehrer, 1938, p. 45) has recently been split by Wolcott (private report), who places the lower mottled formation in the Isnotú and assigns the upper conglomeratic formation to the restricted Betijoque. The Guayabo of the Onia region of western Mérida (Liddle, 1928, p. 335) has received the same treatment.

BETIJOQUE FORMATION (UPPER MIOCENE)

The Betijoque formation is named after the town of Betijoque in west-central Trujillo. The name was coined by Argabrite in 1919 and first published by Garner (1926, p. 682). Liddle (1928, pp. 279–80) described it fully under the term Betijoque beds, but included the Isnotú and Palmar formations. Later in the same year Abadilla (private report) restricted the Betijoque to the upper or conglomeratic part of the section and applied the name Isnotú to the underlying mottled clays and white sandstones. The Palmar formation, which includes the fossiliferous marine shales at the base of Liddle's Betijoque beds, was not named until 1943, when Wolcott introduced it in a company report.

Lithology.—The Betijoque formation is made up of massive beds of conglomerate, sandstone, siltstone, and clay. The conglomerates are the most conspicuous and comprise about 25 per cent of the formation. They are coarser in the upper half of the formation, loosely cemented, poorly sorted and occur in beds up to 12 meters (39 feet) thick. The main constituents are pebbles and cobbles of metamorphic and igneous rocks. The sandstones are massive, locally cross-bedded gray to brown, loosely cemented and friable, poorly sorted, fine- to coarse-grained, micaceous and locally clayey, lignitic, and plant-fossiliferous. The siltstones are massive to thin-bedded, locally well laminated, light gray to greenish gray and micaceous. Excellently preserved remains of leaves and plants occur here and there. The clays constitute the major part of the unit. They are massive, dark greenish gray to locally brown and black, generally sandy, and locally carbonaceous and plant-fossiliferous. Sand-filled crustacean burrows have been observed in the clays of the lower part of the formation. Lateral gradation from clays into siltstones, sandstones, and conglomerates is common.

The formation yields a very complex suite of minerals. Muscovite, garnet, staurolite, tourmaline, zircon, and epidote are abundant; sillimanite, actinolite, hornblende, and zoisite are common, and chlorite, brookite, kyanite, andalusite, titanite, and rutile are rare. The disappearance of epidote corresponds closely with the Betijoque-Isnotú contact.

The type of sedimentation indicates rapid deposition, in part terrestrial, but largely fresh water.

Thickness.—The maximum development of the Betijoque formation occurs in southwestern Trujillo and northern Mérida, where a thickness of 4,365 meters (14,320 feet) has been measured on the Río Buena Vista. The Betijoque thins both south and north of this point, as well as outward from the mountain front. On the Onia structure in southwest Mérida it has a measured thickness of 2,000 meters (6,562 feet), and at Estación La Fría in west-central Táchira a thickness of 1,500 meters (4,921 feet) has been recorded. Northward at the type locality it has a thickness of about 3,500 meters (11,480 feet) but thins to about 500 meters (1,640 feet) south of Bachaquero in the southern part of the District of Bolívar.

Stratigraphic relationship.—The Betijoque appears to be conformable with the underlying Isnotú formation but in some areas overlaps it and lies unconformably on older sediments.

It is overlain unconformably, commonly with high angularity, by the Dividive formation and Recent sediments.

Distribution.—The Betijoque formation occupies a narrow belt along the northwest flank of the Mérida Andes. It appears to pinch out northward in the vicinity of the Bolívar Coastal field. It is probably present under the greater part of the southern basin area.

Age and paleontology.—The age of the Betijoque is considered to be Upper Miocene on its stratigraphic position and on paleobotanical evidence. Berry (1921) cites the following Upper Miocene flora from the type locality.

Blechum betijoquensis Berry
Ficus betijoquensis Berry
Entrada boweni

Correlation.—The Betijoque formation is the exact equivalent of the combined Upper and Middle Maracaibo series of Tash (1937, p. 162) in the District of Sucre, and the Boscán formation of Garner (1926, p. 682) in the enclave of the District of Sucre surrounded by Trujillo, Mérida, and the southeast shore of Lake Maracaibo. It is also the same as the upper part of the Guayabo group in the Onia region of southwestern Mérida (Liddle, 1928, p. 335) and in Táchira (Kehrer, 1938, p. 45), and is probably the same as the upper part of the Guayabo group in the Barco Concession (Notestein, Hubman, and Bowler, 1944, pp. 1203–04) and in the District of Colón (Liddle, 1928, pp. 333–39). The type Onia beds (Hedberg and Sass; 1937, pp. 106–07), or Onia formation (Douglas, 1938, pp. 88–89), form the lower part of the Betijoque section on the Río Onia in southwestern Mérida. A probable correlative of the Betijoque is the Río Yuca formation of Mackenzie (1937, p. 265) in Barinas.

NECESIDAD FORMATION (PLIOCENE)

The Necesidad formation was named by Notestein, Hubman, and Bowler (1944, pp. 1204–05) after Playa Necesidad on the Río de Oro a short distance

above its confluence with the Río Catatumbo in the northwestern part of the District of Colón. The Río de Oro here forms the international boundary with the District of Colón on the north and the north end of the Barco Concession on the south. At the type locality the formation consists of bright red and blue clays interbedded with coarse sandstones which grade into conglomerates with pebbles up to 2 centimeters in diameter. Approximately 50 meters (164 feet) of the formation are exposed but the total thickness is unknown.

The Necesidad is non-marine and lies horizontally on steeply dipping Guayabo near the Río de Oro airport. It is considered Pliocene or possibly Pleistocene in age. The formation is unfossiliferous and its exact correlation is a matter of doubt.

CERRO VIGÍA FORMATION (PLIOCENE)

The name Cerro Vigía formation has been employed in old reports to designate an alluvial fan deposit at Cerro Vigía, a small but steep hill on the trail between Pared Blanca and Los Huevitos not far south of the Río Guasare in the northwestern part of the District of Mara. At the type locality about 100 meters (328 feet) of loose boulders, cobbles and gravel lie unconformably on the Los Ranchos formation. These clastics are chiefly of igneous and metamorphic origin. At Los Melones on the north bank of the Guasare in the southwestern part of the District of Paez, the Cerro Vigía formation has thinned to a mere 5 meters (16 feet) and lies sandwiched between the Los Ranchos and Recent alluvium. Both contacts are probably unconformable.

The formation is unfossiliferous and can be correlated only by lithology and stratigraphic position. The suggestion might be made that the Cerro Vigía is merely a facies of the La Villa formation, but typical La Villa is exposed at Pared Blanca only 2 kilometers east of Cerro Vigía and it is doubtful whether such a rapid transition is possible. It seems much more likely that the Cerro Vigía is Pliocene and correlative with the Tablazos conglomerates of Garner (1926, p. 683) and Liddle (1928, p. 325) in southeastern Miranda and the Coro conglomerate of Liddle (1928, pp. 348–51) in northern Falcón.

EL MILAGRO FORMATION (PLEISTOCENE)

The name El Milagro formation was published first by Liddle (1928, pp. 348–51) and derives from the El Milagro district of the city of Maracaibo, where the formation is exposed in cliffs along the lake shore.

Lithology.—In its upper part the formation comprises light yellow-brown, fine- to medium-grained, micaceous sands and friable sandstones; light gray silts, and light brownish gray, coarse-grained, micaceous, friable sandstones. Some thin layers of dark brown ferruginous sand and buff claystones are present. Thin layers of hard clay ironstone locally provide sufficient resistance to erosion to permit the development of cliffs. The lower part of the formation is dominated by light greenish gray, fine- to coarse-grained and gritty, micaceous, friable sandstones, shaly sandstones, and siltstones. The latter contain locally some light yellow calcareous seams.

The formation yields a complex suite of heavy minerals similar to those of the Betijoque and Dividive.

The type of sedimentation denotes shallow fresh-water deposition at a considerable distance from the source area.

Thickness.—The El Milagro formation varies in thickness from 0 to 150 meters (0 to 492 feet).

Stratigraphic relationship.—The El Milagro lies unconformably on all older formations, and is covered only by Recent alluvium.

Distribution.—The formation is restricted to the northern part of the Maracaibo basin. It has not been reported south of the La Rosa district of the Bolívar Coastal field on the east side of the lake. It is probably present for a considerable distance north, west, and southwest of the type area at Maracaibo.

Age and paleontology.—The true age of the El Milagro is not definitely known but is probably Pleistocene. No fossils are present except silicified wood, which is very common at the base of the formation.

Correlation.—The El Milagro is equivalent to the Dividive formation of the Mérida Andes region and the Mesa formation of eastern Venezuela. An obsolete synonym for the El Milagro is the Maracaibo formation of Garner (1926, p. 683) and Haas and Hubman (1937, pp. 117–18). The second of the two references cited fails to make the necessary distinction between the Maracaibo formation of Garner and the Maracaibo series of Tash (1937, pp. 161–63).

DIVIDIVE* FORMATION (PLEISTOCENE)

The name Dividive formation is introduced at this time to designate the flat, loosely consolidated, post-Betijoque gravels whch are prominently exposed near the village of Dividive on the Agua Viva- Sabana de Mendoza Railway in west-central Trujillo. The name has been used for many years by geologists of the Creole Petroleum Corporation.

Lithology.—The formation consists entirely of massive, commonly cross-bedded, poorly stratified, loosely consolidated, brown, micaceous sands and gravels. The gravels are made up of poorly sorted pebbles and cobbles of igneous and metamorphic rocks which are very similar to those encountered in the conglomerates of the Betijoque formation. Some of the terraces along the Río Chama between the villages of Lagunillas and Estanques in south-central Mérida are composed mainly of reworked red sandstones and conglomerates of the Triassic La Quinta formation. It is possible that Sievers (1888) may have confused these red Quaternary deposits with the true La Quinta sediments of the Triassic.

The sands and gravels of the Dividive yield a complex suite of igneous and metamorphic minerals which is very similar to the assemblage of the Betijoque formation.

* H. D. Hedberg has kindly pointed out that the name Dividive has already been used by Senn (1935) to designate the basal reef limestone member of the Damsite (Caujarao) formation of central Falcón, and that to avoid confusion some other apellation would be preferable. The name Caravajal formation is therefore suggested as a substitute.

The gravels were deposited under fluviatile and terrestrial conditions as alluvial cones, fans, and outwash plains.

Thickness.—The thickness of the formation varies from 0 to 150 meters (0 to 492 feet). The maximum development is along the mountain front, with rapid thinning toward the basin.

Stratigraphic relationship.—The formation is unconformable on all older rocks and is overlapped locally by Recent sediments.

Distribution.—The Dividive gravels are limited to the borders of the elevated regions and attain their maximum development adjacent to the foothills and along some of the valleys of the Mérida Andes, where uplift and renewed erosion have terraced most of them.

Age and paleontology.—The formation contains no fossils and has been assigned to the Pleistocene in view of its position in the section.

Correlation.—The Dividive formation is believed to be equivalent to the El Milagro formation in the northern part of the basin. It is correlated with the Guanapa formation of Mackenzie (1937, p. 266) and the Barinas and Guanare outwash aprons of Liddle (1928, pp. 355–56) in the State of Barinas on the opposite flank of the Andes.

ALLUVIUM (RECENT)

The geology of the greater part of the Maracaibo basin is obscured by the waters of Lake Maracaibo and Recent alluvium deposits. In most places the latter extend from the edges of the bordering mountains to the shores of the lake. Residual soils are found only in the extreme northern part of the basin.

PRODUCING FORMATIONS

At one place or another within the Maracaibo basin, commercial accumulation of oil has been discovered in most of the stratigraphic section from the base of the Middle Cretaceous to the top of the Middle Miocene. The over-all thickness of strata in this sequence, compiled from thicknesses measured in areas where the different formations are productive, is approximately 7,000 meters (23,000 feet). From the standpoint of volume of crude produced, the Lower to Middle Miocene sediments have contributed approximately 90 per cent of the basin's total production to date.

The petroliferous section, and the fields in which the component formations are commercially productive, are here listed.

Formation	*Field*	*Location*
CRETACEOUS		
Apón	Tres Bocas	Barco Concession, Colombia
	Socuavo	Barco Concession, Colombia
	La Paz	District of Maracaibo, Zulia
	Tetones	District of Mara, Zulia
Aguardiente	Petrolea	Barco Concession, Colombia
	Socuavo	Barco Concession, Colombia
Capacho	Petrolea	Barco Concession, Colombia
	La Paz	District of Maracaibo, Zulia
	Tetones (Mara)	District of Mara, Zulia

Formation	*Field*	*Location*
La Luna	Petrolea	Barco Concession, Colombia
	La Paz	District of Maracaibo, Zulia
	Tetones	District of Mara, Zulia
Colón	(Non-productive to date)	
Mito Juan	Río de Oro	Barco Concession, Colombia
Catatumbo	Río de Oro	Barco Concession, Colombia
PALEOCENE		
Guasare	La Paz	District of Maracaibo, Zulia
EOCENE		
Barco (Tabla)	Carbonera	Barco Concession, Colombia
	Tres Bocas	Barco Concession, Colombia
	Socuavo	Barco Concession, Colombia
	Los Manueles	District of Colón, Zulia
	Las Cruces (Tarra)	District of Colón, Zulia
	Río de Oro	District of Colón, Zulia
Los Cuervos	Carbonera	Barco Concession, Colombia
Misoa (Mirador)	Bolívar Coastal (Pueblo Viejo)	District of Bolívar and Lake Maracaibo, Zulia
	Las Cruces (Tarra)	District of Colón, Zulia
	Los Manueles	District of Colón, Zulia
Lower Paují	Mene Grande	District of Sucre, Zulia
Potreritos	Amana	District of Mara, Zulia
	Bolívar Coastal	District of Bolívar and Lake Maracaibo, Zulia
	La Paz	District of Maracaibo, Zulia
	La Concepción	District of Maracaibo, Zulia
	Netick	District of Mara, Zulia
Carbonera	Las Cruces (Tarra)	District of Colón, Zulia
	Los Manueles	District of Colón Zulia
Upper Paují	Mene Grande	District of Sucre, Zulia
Las Flores	Bolívar Coastal	District of Bolívar and Lake Maracaibo, Zulia
	La Concepción	District of Maracaibo, Zulia
Ambrosio	(Non-productive to date)	
OLIGOCENE		
Icotea	Bolívar Coastal	District of Bolívar and Lake Maracaibo, Zulia
MIOCENE		
La Rosa	Bolívar Coastal	District of Bolívar and Lake Maracaibo, Zulia
Lagunillas	Bolívar Coastal	District of Bolívar and Lake Maracaibo, Zulia
Isnotú	Mene Grande	District of Sucre, Zulia

SURFACE INDICATIONS OF PETROLEUM

Oil seepages, gas seepages, and asphalt deposits are distributed extensively along the flanks of the basin (Fig. 6). They are generally associated with Eocene and Cretaceous sediments where these have been uptilted and exposed along the basin edges or on the crests of truncated anticlines.

An outstanding surface accumulation is at Inciarte in the southern part of the District of Mara, Zulia, about 72 kilometers (45 miles) west of Maracaibo city. The asphalt from this seep, which is active at the present time, covers an area of about 12 hectares (30 acres). Wells drilled in the immediate vicinity encountered the basement at shallow depths, beneath a section of post-Eocene sediments. Some oil was generally present along the basement contact. The oil which feeds the Inciarte seepage apparently originates in the truncated Eocene and Cretaceous beds on the east and moves westward up the unconformity to the point of outlet. This may be along a fault or at a point where the basement approaches the surface. During the early years of the present century an attempt was made by private interests to exploit the deposit. A narrow-gauge railroad

37 kilometers (23 miles) long was built from Inciarte northward to Carrasquero on the Río Limón, not far upstream from the river's outlet into Lake Maracaibo. A processing plant was constructed at the river terminal but no asphalt was ever treated. The Government and the operating company were unable to agree on certain financial matters. The railroad was purchased finally by the Government and has since been torn up.

Another surface accumulation of importance is in the La Paz field of the District of Maracaibo, Zulia. This seepage of heavy oil and asphalt covers an area of about 6 hectares (15 acres) on the crest of the La Paz anticline and was largely responsible for the discovery of the field. The oil is apparently derived from the Eocene Potreritos formation, which is exposed along the crest of the fold.

Large seepages of heavy oil are present on the north end of the Mene Grande field in the District of Sucre, Zulia. The discovery well for the field was drilled in their midst and it is certain that the seepages played the decisive role in the selection of the first well location.

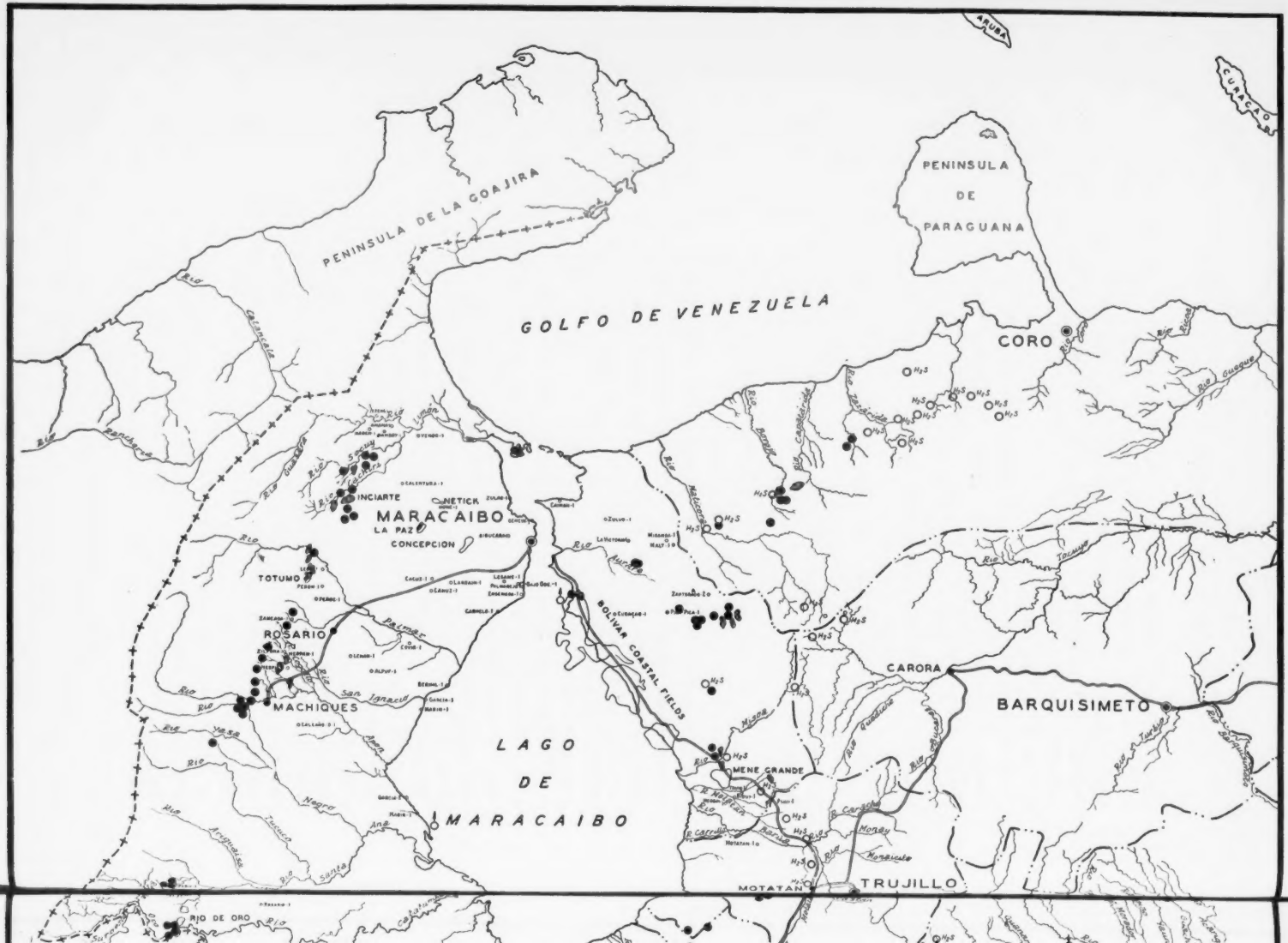
Structure

Regional

The recurrent Cordilleran movements of the Tertiary and Quatenary developed along the same general tectonic lines and have controlled the structure and sedimentation of western Venezuela from the Eocene to the present time. The last and greatest of these movements took place in the late Pleistocene. It lifted the Mérida and Perijá mountains to their present elevations and gave final form to the intervening Maracaibo basin.

The Mérida Range, a geanticline of the first magnitude, is the dominant structural feature of the region. It branches from the Cordillera Oriental in eastern Colombia near the southwestern border of Venezuela and trends northeasterly through the states of Táchira, Mérida, and Trujillo. It plunges rapidly in central Lara and, beyond Barquisimeto, is succeeded by the eastward-trending Coast Range. The uplift has an average width of 90 kilometers (56 miles) and a length of about 400 kilometers (250 miles). The maximum structural relief is in Mérida where elevations of 5,003 meters (16,414 feet) have been recorded. A structural saddle is developed along the main uplift shortly after its divergence from the Cordillera Oriental. This is referred to as the Táchira Gap and until Pleistocene time it served as a connecting channel between the Maracaibo basin and the Apure basin on the south. The Mérida uplift controls the structure along the southeastern flank of the basin throughout the states of Táchira, Mérida, and southern Trujillo.

The Serranía de Trujillo, a folded and faulted spur of the Mérida Andes, branches from the parent uplift in northern Mérida and trends northward into western Lara and eastern Zulia. As it approaches the eastward-trending Maracaibo arch the range swings westward and follows an arcuate trend across the


ARUBA
CURAÇAO
PENINSULA DE LA GOAJIRA
PENINSULA DE PARAGUANA
GOLFO DE VENEZUELA
CORO
INCIARTE
NETICK
MARACAIBO
LA PAZ
CONCEPCION
TOTUMO
ROSARIO
MACHIQUES
LAGO DE MARACAIBO
BOLIVAR COASTAL FIELDS
MENE GRANDE
CARORA
BARQUISIMETO
MOTATAN
TRUJILLO
RIO DE ORO

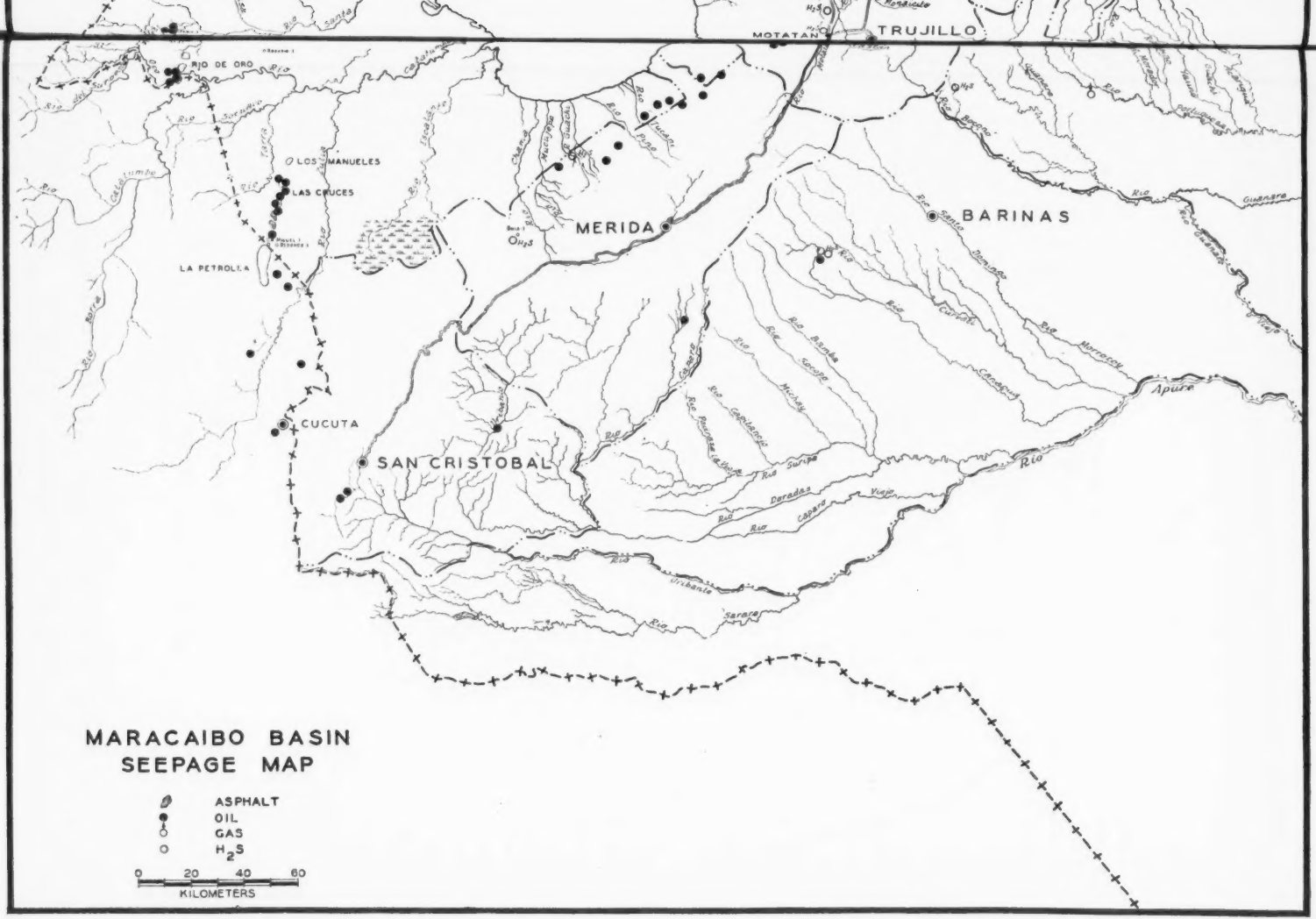

MOTATAN
TRUJILLO
RIO DE ORO
LOS MANUELES
LAS CRUCES
LA PETROLEA
MERIDA
BARINAS
CUCUTA
SAN CRISTOBAL
Rio Apure
MARACAIBO BASIN
SEEPAGE MAP
ASPHALT
OIL
GAS
H_2S
0 20 40 60
KILOMETERS

FIG. 6

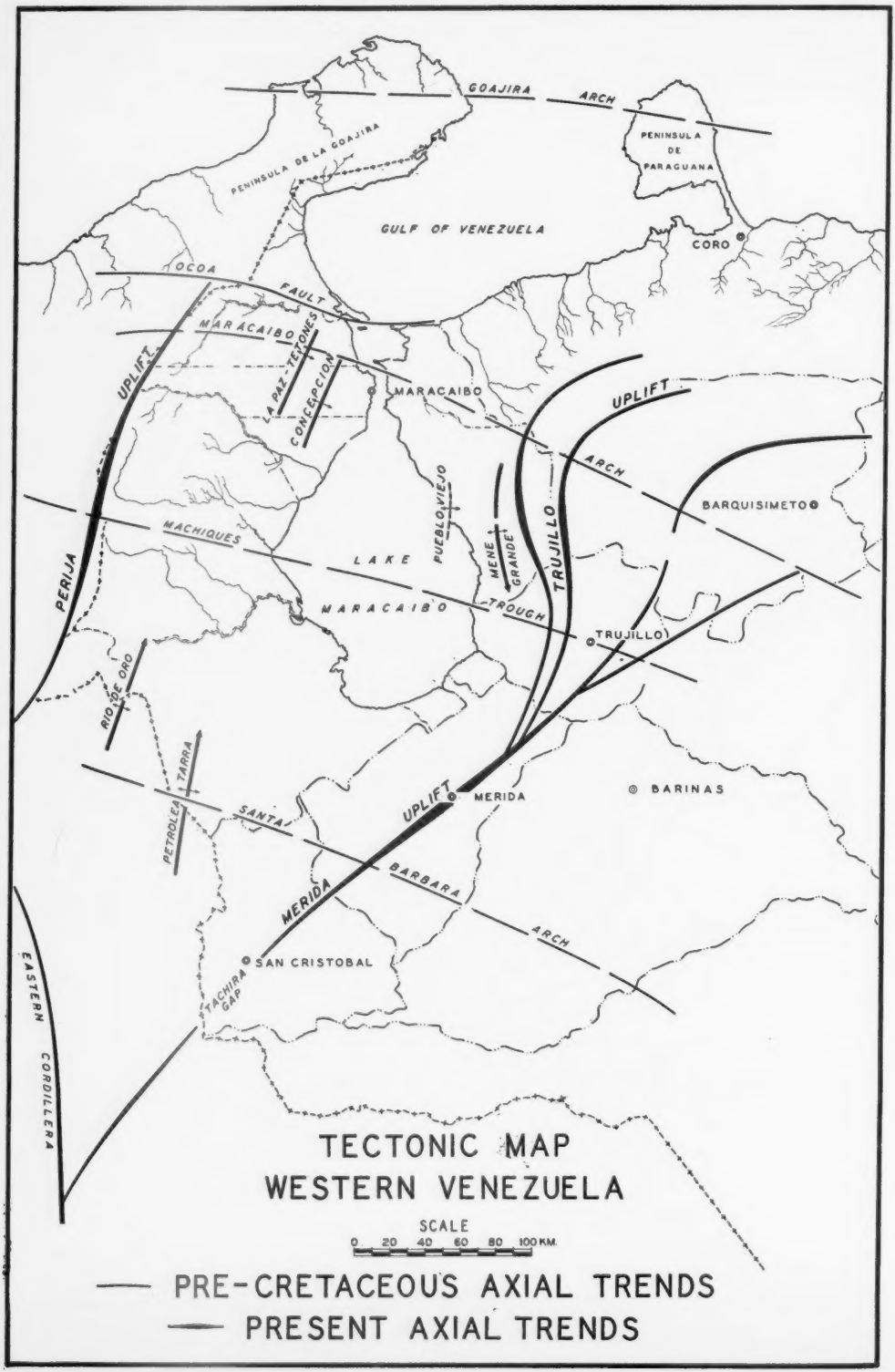

GOAJIRA ARCH
PENINSULA DE LA GOAJIRA
PENINSULA DE PARAGUANA
GULF OF VENEZUELA
CORO
OCOA FAULT
MARACAIBO UPLIFT
MARACAIBO
LA PAZ-TETONES
CONCEPCION
UPLIFT
ARCH
BARQUISIMETO
PUEBLOVIEJO
MENE GRANDE
TRUJILLO
MACHIQUES
LAKE MARACAIBO TROUGH
PERIJA
TRUJILLO
RIO DE ORO
TARRA
PETROLEA
SANTA
UPLIFT
MERIDA
BARINAS
BARBARA
MERIDA ARCH
SAN CRISTOBAL
TACHIRA GAP
EASTERN CORDILLERA
TECTONIC MAP
WESTERN VENEZUELA
SCALE
0 20 40 60 80 100 KM.
PRE-CRETACEOUS AXIAL TRENDS
PRESENT AXIAL TRENDS

FIG. 7

arch. North of the arch the range swings abruptly eastward and follows this course into Falcón.

The Maracaibo arch, which trends eastward across the northern end of the Maracaibo basin, has existed since pre-Mesozoic time, and has at all times exerted a strong influence on the structure and stratigraphy in its immediate vicinity. It is suggested here that the arcuate trend of the Serranía de Trujillo follows a line of weakness in a thick sequence of Cretaceous and Eocene sediments which were deposited in a depressed area along the old Maracaibo arch.

The Perijá uplift, a continuation of the Cordillera Oriental of eastern Colombia, follows a northward course along the Colombian-Venezuelan boundary. It has a length of almost 400 kilometers (250 miles) and an average width of 60 kilometers (37 miles). From its point of departure in Colombia, the uplift plunges rapidly to the Catatumbo Gap near the boundary with Venezuela. From this low area, where elevations are less than 300 meters (984 feet), a steady northward structural rise takes place into the western part of the District of Perijá, where elevations approaching 3,000 meters (9,842 feet) are recorded. From this point northward the structure plunges continuously until it is terminated against the eastward-trending Ocoa fault.

Lying between the diverging Mérida and Perijá uplifts and limited on the east and north by the Serranía de Trujillo and Maracaibo arch, is the Maracaibo basin. Regionally it reflects a structural depression surrounded by bordering highlands. The orogeny which followed the close of Eocene deposition and resulted in the elevation of most of western Venezuela, folded and faulted the older sediments which now underlie the basin. The intensity of the folding and faulting diminished basinward but the trends remained generally parallel with those of the major uplifts. The basin area remained above sea-level throughout a long part of the Oligocene and was subjected to intense erosion. The folds were truncated and the surface levelled. The major unconformity of the post-Cretaceous is present along this break. The basin subsided and younger sediments were laid down on the post-Eocene erosion surface. Succeeding orogenies rebuilt the bordering mountains but during none of these were the interior basin sediments subjected to the widespread folding and faulting of the early Oligocene orogeny.

A number of structural trends parallel with, and subordinate to, the bordering highlands are present along the eastern and western flanks of the basin. They were outlined originally at the close of the Eocene and have been subjected to renewed folding and faulting during succeeding periods of uplift. It is along these trends that the outlying oil fields of the Maracaibo basin are located. Only the most important are here listed.

PRODUCING STRUCTURES

PETROLEA-TARRA ANTICLINORIUM

This feature branches from the Sierra de Perijá, immediately north of the bifurcation of the Cordillera Oriental. It plunges northward and follows a sinuous

course, slightly east of north, over a distance of at least 120 kilometers (75 miles). It passes through the Barco area of Colombia and continues into the District of Colón, Zulia, in western Venezuela. On the east lies the Zulia syncline and on the west the Sardinata structural depression. Cretaceous rocks are exposed along the crest of the uplift in the Barco area but northward down the plunge they are followed by successively younger formations until the structure disappears beneath the flood plain of the Río Catatumbo. Near its northern end the fold is outlined in sediments of the Miocene which indicates movement along this trend in post-Miocene time.

Three local structures are present along the major uplift in the Barco area and have been described in detail by Notestein, Hubman, and Bowler (1944, p. 1207). The most important of these is the Petrolea anticline on which the Petrolea field is located.

From the Colombian border the anticlinorium, by now reduced in size and referred to as the Tarra anticline, continues northward into Venezuela over a distance of approximately 50 kilometers (31 miles). It is reflected clearly in the topography and the numerous oil seepages along its crest aroused the interest of early investigators. At the Colombian border the fold is highly asymmetric with a short vertical to overturned west flank and a comparatively broad and gentle east flank. About 14 kilometers (9 miles) north of the border a rather abrupt reversal in the structural attitude is noted. The west flank dips diminish rapidly, the fold broadens, and movement from the west has thrust the western limb of the anticline far over the eastern one. Drag folding along the fault has overturned the beds along the east flank.

Las Cruces dome.—At Las Cruces, about 20 kilometers (12.5 miles) north of the Colombian border, local closure is present on the overthrust fault block. This is reflected in the bedded sediments of the Eocene which are present at the surface. The structure is a relatively broad, flat-crested, elongate dome that plunges gently northward. South reversal against the regional plunge has developed effective closure over a length of approximately 8 kilometers (5 miles) and a width of 2.5 kilometers (1.5 miles). Drilling on the high part of the closure has established a depth to the overthrust of about 1,000 meters (3,280 feet). The fault has a westward dip of about 28° and the west flank of the original anticline has been pushed eastward along the fault for a distance of about 1,200 meters (3,937 feet). The section lying above the fault comprises the lower Carbonera (Sandy shale horizon), Misoa (Mirador), Barco, and Los Cuervos (Third Coal horizon) formations. This section is repeated below the fault. The Misoa and Barco formations are productive on the overthrust block and the Carbonera, Misoa, and Barco formations are productive below the fault.

At El Cubo, about 5 kilometers northward from Las Cruces, local closure is present in association with secondary faulting along the crest of the parent feature. A small amount of heavy oil has been obtained at shallow depths in this area from basal sands of the Carbonera formation (sandy shales).

Los Manueles dome.—At Los Manueles, about 10 kilometers (6 miles) north

from El Cubo, is another area of local closure on the overthrust block of the main fault. It is similar to that at Las Cruces but much smaller. The closure is clearly outlined at the surface in an area of Miocene outcrops which are entirely surrounded by younger sediments. The structure exhibits a relatively broad, gently dipping west flank and a vertical to overturned east flank that terminates against the major thrust in the subsurface. The surface trace of the fault is obscured by the mantle of recent sediments which cover the area on the east. Closure in the subsurface is entirely against the major thrust and shifts westward in successively older formations.

At Los Manueles, the Carbonera and Misoa (Mirador) formations of the Upper Eocene and the Barco formation of the Lower Eocene are productive on the overthrust fault block.

RÍO DE ORO ANTICLINE

The Río de Oro anticline lies in the eastern foothills of the Sierra de Perijá about 50 kilometers (31 miles) northwest from the Tarra anticline. It trends slightly east of north over a distance of about 50 kilometers (31 miles) from the Río Catatumbo in Colombia to the Río Lora at the northern boundary of the Colón District of Zulia in Venezuela. The structure is about equally divided between the two countries. In the extreme south, Cretaceous rocks are exposed along the crest but northward down the plunge these are overlain by successively younger Tertiary sediments until the structure terminates in the gently dipping Miocene beds north of the Río Lora. The anticline is narrow, faulted and highly asymmetric with a nearly vertical east flank and comparatively gentle west flank. Numerous oil and gas seepages are present along its crest.

Commercial accumulation of oil is confined to local highs along the main trend. In the northern Barco area, adjacent to the Colombian-Venezuelan border commercial production has been developed in the Mito Juan formation of the Upper Cretaceous. On the Venezuelan side of the border several wells have been drilled and found productive in the Barco formation. These are shut in at the present time.

The oil fields located on the Tarra and Río de Oro anticlines in Venezuela are owned and operated by the Colón Development Company, a Shell Company subsidiary. Those located in the adjacent Barco Concession of Colombia are owned and operated by the Colombian Petroleum Company, a Socony Vacuum-Texas Company subsidiary.

Along the high northwestern flank of the basin are several structural zones which trend northeasterly through the districts of Urdaneta, Maracaibo, and Mara, Zulia. They are parallel with the major Perijá uplift and reflect its recurrent structural movements. Along these subsidiary trends are located the oil fields in this part of the basin.

LA PAZ-TETONES UPLIFT

The La Paz-Tetones uplift is located about 40 kilometers (25 miles) northwest from the city of Maracaibo and trends northeasterly through the districts

of Maracaibo and Mara, Zulia. It has been traced on the surface over a distance of 30 kilometers (19 miles) and gravimetric studies have shown that it continues in the subsurface for several kilometers beyond either end of its surface expression. Sediments of the Upper Eocene Las Flores and Potreritos formations are exposed over local highs along the main trend. Broad gentle synclines separate the uplift from the Concepción fold on the east and the uptilted foothill belt of the Perijá Range on the west. Three areas of local closure which have proved productive will be considered separately.

La Paz anticline.—The La Paz anticline is located in the District of Maracaibo 45 kilometers (28 miles) almost due west from Maracaibo city. It trends N. 35° E. and occupies a high structural position on the southern part of the La Paz-Tetones uplift. The structure is reflected faintly in the topography but attention probably was drawn first to the locality by the large oil and asphalt seepages which cover an area of about 6 hectares (15 acres) on the crest of the anticline. Early studies revealed the near-surface presence of the Upper Eocene Potreritos formation and it was possible by pitting to outline the fold along a distance of approximately 10 kilometers (6 miles) and to define its flank contacts with overlying sediments. The Upper Eocene Las Flores formation, present in adjacent areas, has been eroded from the crest of the fold and overlapped by younger Miocene sediments. Later checking with the torsion balance showed the structure to continue southwestward in the subsurface for a distance of about 10 kilometers (6 miles) beyond its surface expression.

On the high part of the anticline in the vicinity of the asphalt seepages, the structure is nearly symmetrical. Dips along the axis approach 90° but diminish rapidly down the flanks, which are concave upward. The vertical axial plane appears to be a zone of flowage and crushing, in which the sediments are highly contorted. At one point a large block of Guasare formation limestone has ridden to the surface from a depth of several hundred feet. This flowage zone was no doubt the migratory channel for the oil which forms the large surface accumulation. Northeastward down the plunge the fold broadens and becomes asymmetric, with a steep west flank and broad gentle east flank.

The formations which make up the section in the La Paz field and their approximate maximum thickness are the following.

	Feet
Potreritos formation (Upper Eocene)	1,500
Guasare formation (Paleocene)	1,500
Mito Juan-Colón formation (Upper Cretaceous)	1,600
La Luna formation (Upper Cretaceous)	500
Capacho (Upper Cogollo) formation (Middle Cretaceous)	1,200

Early drilling at La Paz was confined largely to the crestal and immediately adjacent flank areas and the oil was produced almost entirely from the Guasare formation. Some isolated sand bodies in the overlying Potreritos were productive but most of the oil from this formation had escaped to the surface. It was a field

of shallow production and the first 35 wells drilled had an average depth of only 1,400 feet.

In the latter part of 1944, deeper drilling on the east flank encountered prolific Cretaceous limestone production in the La Luna formation at a depth of approximately 5,000 feet. Economically, this was an extremely important discovery. It marked the first discovery of commercial Cretaceous production in the Venezuelan part of the Maracaibo basin. Prior to this time commercial Cretaceous production had been limited to the Barco area of eastern Colombia.

The La Paz field is owned and operated by Venezuelan Oil Concessions, Ltd., a Shell Company subsidiary.

Netick anticline.—The Netick anticline is located in the southern part of the District of Mara, Zulia, and about 11 kilometers (6 miles) northward and *en échelon* toward the west with the La Paz anticline. It trends N. 35° E. and is essentially a thrust which brings up beds of the Eocene Las Flores formation on the east against late Miocene sediments on the west. Closure is present against the fault on the upthrown side. The main fault dips steeply and has a displacement exceeding 1,000 feet. Subsidiary faulting and folding are common and give rise to a complex structural pattern. The structure is reflected only faintly in the topography but has been traced by pitting over a distance of about 5.5 kilometers (3.5 miles). By this means the trace of the fault has been defined clearly and the Eocene contact outlined. The structure is narrow and steep with east flank dips ranging from 35° to 70°. Local folding is common in the post-Eocene sediments west of the fault.

Drilling in the Netick field has penetrated a section comprising the Las Flores and Potreritos formations of the Upper Eocene, the Guasare formation of the Paleocene, and the Mito Juan-Colón formation of the Upper Cretaceous. The section is comparable with the equivalent sequence in the La Paz field.

Commercial oil production from the field has been obtained so far, from sands within the Potreritos formation. The accumulation is scattered and dependent entirely on local structural conditions. Six wells have been drilled to date, only three of which are productive, and the possibilities are poor for developing important production in the Eocene. The discovery of Cretaceous production at La Paz and Tetones has added greatly to the prospects for deeper production.

The Netick field is owned and operated by the Orinoco Oil Company, a subsidiary of the Pure Oil Company.

Tetones anticline.—The Tetones anticline is located in the District of Mara, Zulia, about 10 kilometers (6 miles) northward from the Netick field and along the same fault trend. The structure is similar to that at Netick and is outlined at the surface by a narrow belt of Upper Eocene sediments which have been thrust steeply westward against beds of the Miocene. The section, established by drilling, comprises the Las Flores and Potreritos formations of the Upper Eocene, Guasare formation of the Paleocene, and the Mito Juan, Colón, La Luna, and Capacho (Upper Cogollo) formations of the Cretaceous.

Early in 1945 commercial production in substantial amounts was discovered in the limestones of the La Luna formation at a depth of about 6,000 feet. The field is in its initial development stage and no reliable estimates can be made concerning its future prospects. It is owned and operated by the Caribbean Petroleum Company, a Shell Company subsidiary.

Kilometer-24 anticline.—About 5 kilometers (3 miles) south of Tetones is a broad domal uplift on the same regional trend and referred to as the Kilometer-24 anticline. The uplift is reflected in the topography and outlined clearly at the surface in an area of Upper Eocene sediments which are encircled completely by overlapping Miocene beds. The Eocene and Paleocene have been tested and found non-productive at this locality but there are fair prospects for deeper Cretaceous production.

LA CONCEPCIÓN STRUCTURE

La Concepción structure lies 25 kilometers (15 miles) west from Maracaibo city. It occupies a high structural position on the southern part of the Concepción-Cañadones uplift, a broad regional feature which trends northeastward through the districts of Maracaibo and Mara, Zulia. Within the area covered by La Concepción field, the structure comprises at least two well defined, crestal faulted anticlines. The larger one, referred to as Ramillete, lies immediately north, and *en échelon* toward the west, with the smaller Los Teques anticline. The structure is reflected faintly in the topography and the presence of bedded Upper Eocene sediments within a few feet of the surface has permitted accurate mapping of a large part of the surface structure.

The Los Teques anticline trends N. 50° E. over a distance of about 4 kilometers (2.5 miles) and the fold is nearly symmetrical with flank dips averaging about 30°. A large fault occupies the axial position and although closure is present against the fault on both flanks, production is limited almost entirely to a small area on the western upthrown block.

The fault extends northeastward, probably with increasing displacement, well beyond the limits of the anticline and is paralleled about 600 meters northwest by a secondary fault which follows the axis of the larger Ramillete anticline. This structure is comparatively broad and asymmetric, with west flank dips of 15° and 20° and east flank dips as high as 60°. The fault is downthrown toward the east but the displacement probably does not exceed 200 feet. The area of proved production is about 4 kilometers (2.5 miles) long and has an average width of 2 kilometers (1.3 miles).

The present known accumulation at La Concepción occurs in the Las Flores formation of the Upper Eocene. At Los Teques the average depth to the main producing zone is between 1,200 and 1,300 feet, although minor production has been obtained at much higher levels. At Ramillete, the higher Los Teques sands are generally barren or missing but the main sand is present and productive at slightly greater depths. A deeper sand, however, accounts for the greater part of the production. It is about 800 feet lower in the section and is absent or barren

at Los Teques. The productive area at Ramillete is about 4 kilometers (2.5 miles) long and has an average width of 2 kilometers (1.3 miles).

The foregoing description of the structure at La Concepción is based on very limited reliable data but the general picture is believed to be essentially correct.

La Concepción field is owned and operated by Venezuelan Oil Concessions, Ltd., a Shell Company subsidiary.

MENE GRANDE ANTICLINE

The Mene Grande anticline is located in the District of Sucre, Zulia, on the east side of Lake Maracaibo and 120 kilometers (75 miles) southeast from the city of Maracaibo. The structure lies on the east flank of the basin and occupies a position on the southern continuation of the Cerro Misoa, a southward-plunging spur of the Serranía de Trujillo. The Cerro Misoa is a prominent anticlinal mountain formed by the resistant sandstone beds of the Misoa formation and flanked by the less resistant shales of the overlying Paují formation. It is faulted along its western flank but southward the fault decreases and dies out in the steeply dipping west flank of the Mene Grande anticline. It is difficult to estimate the over-all closure at Mene Grande since there appears to be little, if any, saddling separating it from the Misoa Range proper. The structure plunges southward, is relatively broad and flat-crested, and has a steeply dipping west flank.

The section, established by drilling, comprises 75 to 100 feet of recent sediments, the Isnotú formation of the Middle Miocene, and the Paují and Misoa formations of the Upper Eocene. There is marked angular discordance at the base of the Isnotú formation and the structure in the underlying Eocene is reflected clearly by the non-conformable contact.

The Isnotú formation has a thickness of approximately 1,000 meters (3,280 feet) in the crestal area of the Mene Grande field and its basal 300 meters (984 feet) embraces a zone of lenticular sands that are productive over a large area and have accounted for about 84 per cent of the field's total production. The gravity of the oil is from 14° to 18° A.P.I.

The underlying Eocene is productive from both the Upper and Lower Paují but the accumulation is confined to areas of local closure along the crest of the main structure.

The Upper Paují formation has a thickness of 152 to 183 meters (500 to 600 feet) and production is obtained from a zone about 76 meters (250 feet) thick in the upper middle part. The Lower Paují oil is produced from a 30 meter (100 feet) zone in the upper part. The oil from the Eocene has a gravity range from 25° to 30° A.P.I.

The Mene Grande field is owned and operated by the Caribbean Petroleum Company, a subsidiary of the Shell Company.

BOLÍVAR COASTAL FIELD

The Bolívar Coastal field, one of the outstanding oil fields of the world, is situated on the northeastern flank of the Maracaibo basin. It straddles the east-

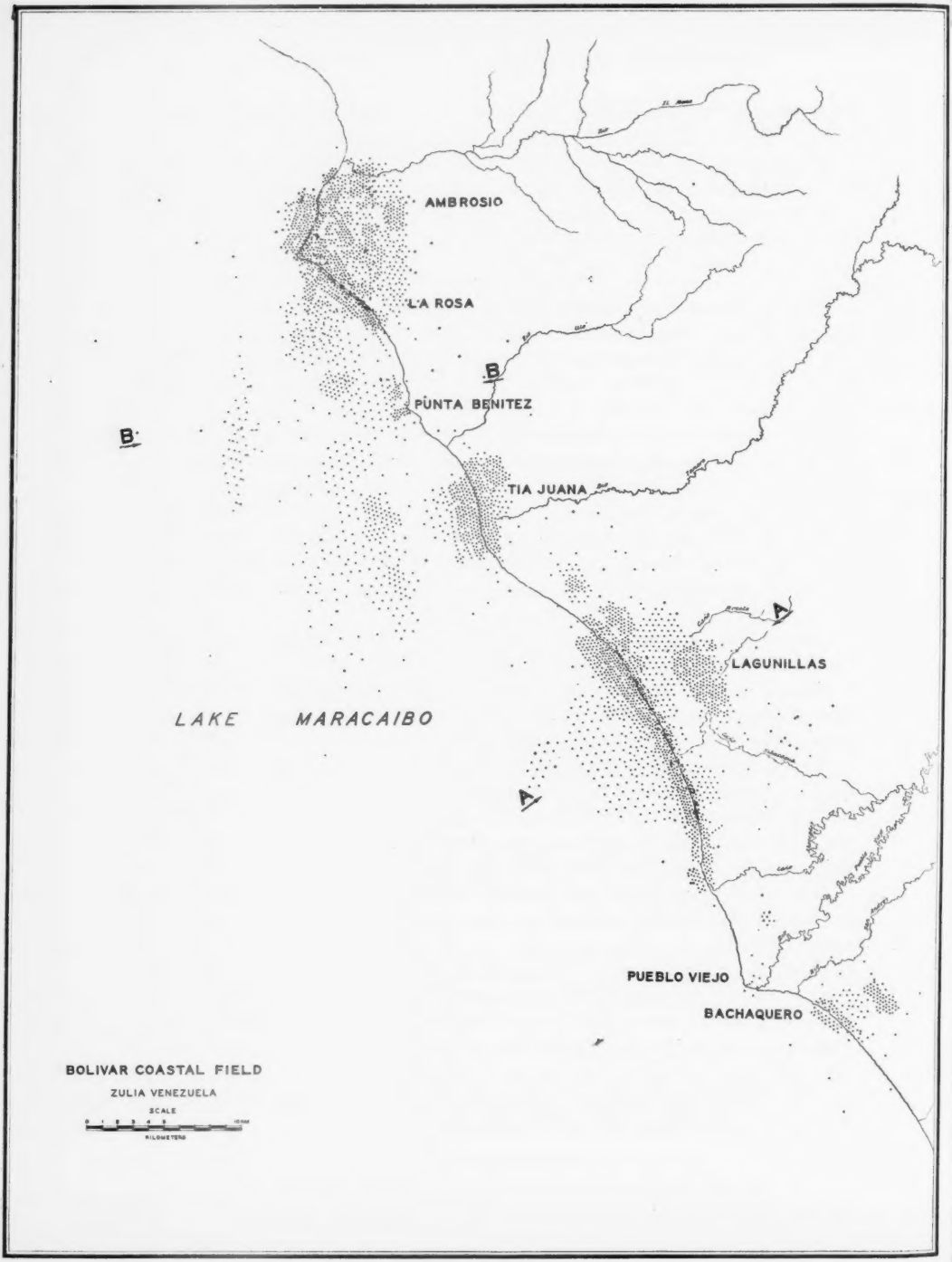

AMBROSIO
L'A ROSA
B
PUNTA BENITEZ
B
TIA JUANA
A
LAGUNILLAS
LAKE MARACAIBO
A
PUEBLO VIEJO
BACHAQUERO
BOLIVAR COASTAL FIELD
ZULIA VENEZUELA
SCALE
KILOMETERS

FIG. 8

tern shore of Lake Maracaibo over a distance of 70 kilometers (42.5 miles), from the area of Eocene outcrops in the Ambrosio district, southward to Bachaquero. The width varies considerably and reaches its maximum of 16 kilometers (10 miles) in the Tía Juana and Lagunillas areas (Fig 8).

The geologic section penetrated in the field to date has a composite thickness exceeding 5,273 meters (17,380 feet) and embraces formations extending from the Upper Eocene to Recent. These formations and their approximate maximum thicknesses are given in the following tabulation.

Age	*Formation*	*Approximate Thickness*	
		Meters	*Feet*
Recent	Alluvium	24	80
Pleistocene	El Milagro	640	2,100
Miocene	La Puerta	670	2,200
	Lagunillas	305	1,000
	Las Rosa	183	600
Oligocene	Icotea	140	460
Eocene	Ambrosio	110	360
	Las Flores	1,311	4,300
	Potreritos	879	2,880
	Misoa	1,036	3,400
	Total	5,298	17,380

At one place or another within the field, all of these formations, with the exception of the Ambrosio, La Puerta, El Milagro, and Recent are commercially productive. The most important reservoirs from the standpoint of volume of crude produced have been in the lower Lagunillas and La Rosa formations of the Miocene, and have accounted for approximately 98 per cent of the field's total production. The Potreritos formation of the Eocene accounts for most of the remainder.

These percentages are in no sense a true reflection of the relative Eocene and Miocene potentials. Throughout the first 20 years of the field's life it was the practice to stop drilling as soon as the unconformity had been reached and only during the past 6 years has the Eocene received serious consideration. It is almost certain that the future will show a progressive increase in the Eocene share of the overall potential.

The Bolivar Coastal field occupies a high structural position on the northeastern rim of the basin. The structure in the post-Eocene sediments is essentially monoclinal and dips southwest from 2° to 10° (Fig. 9). These dips reflect the attitude of the underlying post-Eocene erosion surface which formed the basin floor upon which the younger sediments were deposited. The areas of oil accumulation in the post-Eocene sediments are dependent almost entirely on the type of sedimentation, with local structure playing only a minor role.

In the Lagunillas area the structural range of the post-Eocene accumulation is approximately 3,000 feet and extends from the updip zone of tar sands and meteoric waters at about 2,000 feet subsea, referred to the Eocene contact, to the downdip edge-water limit at 5,000 feet subsea. Northward from Lagunillas the boundaries of the post-Eocene range of accumulation rise higher on the Eocene

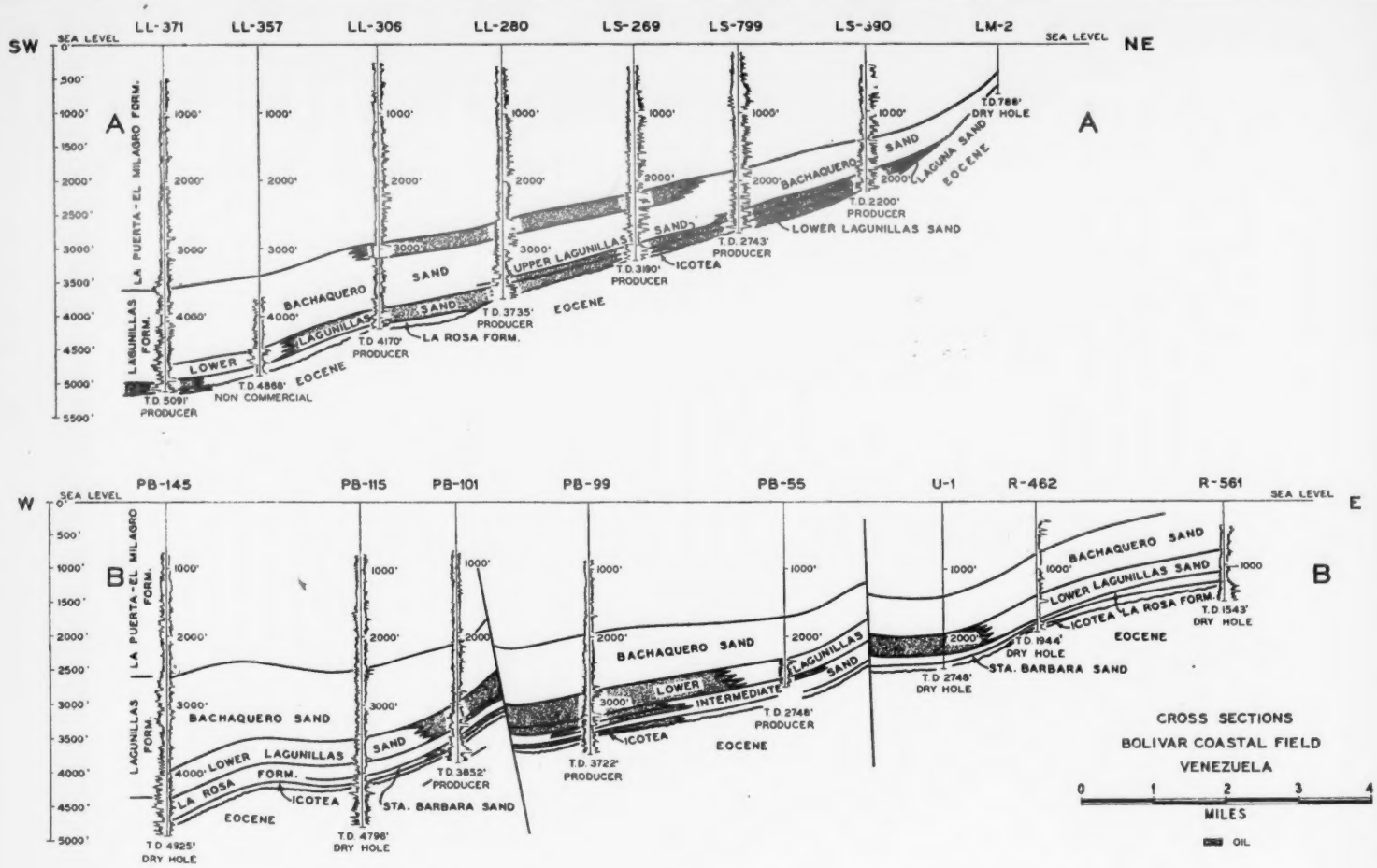

SW
NE
SEA LEVEL
LL-371
LL-357
LL-306
LL-280
LS-269
LS-799
LS-390
LM-2
A
A
LA PUERTA - EL MILAGRO FORM.
LAGUNILLAS FORM.
BACHAQUERO
SAND
LAGUNILLAS
LOWER
UPPER LAGUNILLAS
LOWER LAGUNILLAS SAND
LAGUNA SAND
ICOTEA
LA ROSA FORM.
EOCENE
T.D. 5091' PRODUCER
T.D. 4868' NON COMMERCIAL
T.D. 4170' PRODUCER
T.D. 3735' PRODUCER
T.D. 3190' PRODUCER
T.D. 2743' PRODUCER
T.D. 2200' PRODUCER
T.D. 788' DRY HOLE
W
E
PB-145
PB-115
PB-101
PB-99
PB-55
U-1
R-462
R-561
B
B
BACHAQUERO SAND
LOWER LAGUNILLAS
LA ROSA FORM.
ICOTEA
EOCENE
STA. BARBARA SAND
INTERMEDIATE
T.D. 4925' DRY HOLE
T.D. 4796' DRY HOLE
T.D. 3852' PRODUCER
T.D. 3722' PRODUCER
T.D. 2748' PRODUCER
T.D. 2748' DRY HOLE
T.D. 1944' DRY HOLE
T.D. 1543' DRY HOLE
CROSS SECTIONS
BOLIVAR COASTAL FIELD
VENEZUELA
0 1 2 3 4
MILES
OIL

FIG. 9

floor, probably in keeping with the regional northward rise of the basin. In the Ambrosio area commercial accumulation is present from about 500 feet subsea to 3,500 feet subsea, referred to the Eocene contact.

Accumulation in the underlying Eocene is both structural and stratigraphic. It is generally associated with faulting and truncated folds which have been sealed off along the unconformity, but it is almost certain that true structural accumulation is present in older beds which were not affected by the post-Eocene erosion.

The deepest stratigraphic penetration is at Pueblo Viejo, in the southern part of the field, where commercial accumulation is present in the Misoa formation along the crest of the Pueblo Viejo uplift. This structure is outlined in the buried Eocene topography and appears to be a narrow, steeply dipping, highly faulted anticline that plunges southward beneath the younger non-conformable Miocene sediments. The structure probably was formed during the early Oligocene orogeny and remained above sea-level until Middle Miocene time. The younger Eocene Paují formation was eroded from the crest and at the present time sediments of the upper Lagunillas rest with angular unconformity on the Misoa formation. The only surface expression of the uplift is in the configuration of the lake shore line.

The presence of the Pueblo Viejo structure has been known for many years, but it was not until the latter part of 1944 that the Shell Company, after many attempts, was successful in developing commercial production. The Misoa formation is present at comparatively shallow depths and the discovery well encountered commercial accumulation at 2,274 feet. Successful completion of wells is a serious problem due to high dips and complex faulting.

The Bolívar Coastal field is owned and operated by the Creole Petroleum Corporation, Venezuelan Oil Concessions, Ltd. (Shell Company subsidiary), and the Mene Grande Oil Company (Gulf Company subsidiary). Venezuelan Oil Concessions, Ltd. own all of the land-based acreage while Creole's concessions lie entirely within the lake. Mene Grande Company's holdings lie within the lake but are confined to a one-kilometer strip adjacent to the shore line.

In 1945, the Bolívar Coastal field accounted for almost 58 per cent of Venezuela's total production and probably between 7 and 8 per cent of the total reported world production.

Geologic History

The formation of the present Maracaibo basin represents the culmination of a long series of structural and stratigraphic events which are as yet only partially solved. Prior to the late Eocene, which initiated the first of the Cordilleran movements, the topographic and structural trends of the landmasses in the present Colombian-Venezuelan region were generally east-west and more or less parallel with the Guayana shield, which has existed, largely in its present form, since early Mesozoic time. Off the present north coast of Venezuela, so-called Paria Land

occupied an extensive area that is now largely covered by the waters of the Caribbean Sea. The Goajira and Paraguaná peninsulas and the offshore island chain are probably remnants of this old land. Their grain is east-west. On the south another positive area, the Maracaibo arch, struck eastward across the northern end of the present Maracaibo basin. It is reflected in the later structure and stratigraphy and separates the Maracaibo basin from the Gulf of Venezuela. A third landmass, the Santa Barbara arch, was present farther southward and passed through Santander del Norte in eastern Colombia and southern Mérida and Táchira in Venezuela. Lying between the two latter arches was the Machiques trough which extended westward into Colombia and eastward approximately through the middle of the area now covered by Lake Maracaibo. These old land trends and intervening depositional troughs are clearly reflected in the distribution of the pre-Eocene sediments.

Widespread deposition occurred during the Ordovician, Devonian, Permo-Pennsylvanian, and Triassic but each of these was followed by a long period of uplift, diastrophism, and erosion, so that only remnants of the original deposits are now present in the uplifted areas.

The beginning of the Cretaceous witnessed a progressive transgression of the sea into Colombia, probably from the south and west which, in Lower Cretaceous time entered the Machiques trough in western Venezuela and laid down the thick sandstones and conglomerates of the Río Negro formation. By Middle Cretaceous time the sea had established a connection with the Atlantic at the northeast and all of Venezuela north and west of the Guayana shield was invaded. Shallow sea conditions prevailed and widespread deposition of sandstones and fine conglomerates took place. Deposition was continuous into upper Middle Cretaceous time and the initial sandstone deposits were succeeded by the limestones and shales of the Apón formation.

Gentle regional uplift and withdrawal of the sea in upper Middle Cretaceous time was followed shortly by another widespread marine transgression and, with minor interruptions, deposition was continuous until near the close of the Cretaceous. This second major depositional cycle followed closely the pattern of the first. Shallow seas were generally prevalent and the initial sandstone deposits of the Aguardiente formation were followed by the shallow to deeper marine limestones and shales of the Capacho, La Luna, Colón, Mito Juan, and Catatumbo formations. The sea probably attained its maximum depth in La Luna time.

The closing period of the Cretaceous witnessed a gentle regional uplift which was continuous into the early Paleocene. Subsidence began again in the Upper Paleocene and the shallow-marine and brackish-water sediments of the Guasare formation were deposited over a restricted area along a previously established depositional trend. These were followed in the early and middle Eocene by the fresh water and lagoonal deposits of the coal-bearing Marcelina formation and the marine shales of the Trujillo formation.

Widespread subsidence with slow to rapid deposition was generally characteristic of the Upper Eocene. The shallow-water deposits of the Misoa formation were laid down over an extensive area and were followed by the deeper marine sediments of the Paují formation.

The absence of angular discordance along the time breaks which separate the cycles of deposition, bears witness to the stability of the land during the Cretaceous, Paleocene, and Eocene.

The early Oligocene was a period of regional elevation and the consequent withdrawal of the sea from most of western Venezuela. Uplift and major diastrophism in the Mérida and Perijá areas initiated the first movement along the present Cordilleran trends. The Caribbean Coast Range was formed at this time and the Maracaibo basin received its approximate present outline. A long period of erosion followed until the closing stages of the Oligocene when the Maracaibo basin, which had existed as dry land since the close of the Eocene, began subsiding in its northern part and received fresh-water and terrestrial sediments from the surrounding highlands. Restricted areas of marine deposition are present in the extreme northeastern and southwestern parts of the basin. The Icotea was deposited in depressions on the eroded Eocene surface in the northern part of the basin and the thick fresh-water beds of the El Fausto formation were laid down along the Perijá mountain front. Further movement, with accompanying faulting and folding took place along the established trends at the very close of the Oligocene or immediate beginning of the Miocene (second Cordilleran movement).

Subsidence during the early Miocene permitted an expanding sea from the northeast to enter the Maracaibo basin through a narrow channel across western Falcón and the basin received its first extensive marine deposits since the Eocene. These are represented in the La Rosa, basal Lagunillas, and equivalent formations. The sea again withdrew and the remaining Middle and Upper Miocene were largely periods of recurrent uplift and widespread deposition of fresh- to brackish-water sediments with short local marine incursions. The Lagunillas, La Puerta, and equivalent formations were deposited at this time. In the southern lake area subsidence was rapid and during the late Miocene the thick fresh water and terrestrial deposits of the Betijoque formation were laid down along the borders of the rejuvenated mountains.

A period of uplift and erosion at the close of the Miocene (third Cordilleran movement) was succeeded in the Plio-Pleistocene by extensive terrestrial deposition throughout the basin area (Cerro Vigía-El Milagro formations). During the late Pleistocene the last and greatest of the regional orogenies took place (fourth Cordilleran movement). The Mérida and Perijá mountains were rejuvenated and lifted to their present heights. Most of Paria Land, which had begun to subside in the Pliocene, disappeared beneath the waters of the Caribbean Sea and the eastward trending Ocoa fault was formed. Extensive faulting and folding occurred on the flanks of the basin, generally along the trends already established.

The southern part of the lake subsided rapidly with the vast load of sediments received from the near-by rejuvenated mountains and this subsidence has continued to the present time.

Development

The widespread distribution of oil seepages and asphalt deposits throughout the Maracaibo basin aroused the interest of early explorers but it was not until the years immediately preceding the first World War that the major oil companies became actively interested in the area. The Shell Company led the way and obtained large concessions in the State of Zulia. Some of these covered the entire districts of Bolívar, Colón, and Maracaibo while others included large areas in the districts of Mara, Perijá, and Sucre. In 1914 this company discovered the Mene Grande field on concessions held by the Barber Asphalt Company east of Lake Maracaibo in the District of Sucre, Zulia. The discovery well MG-1 was drilled in a large seepage area on the north end of the field and found production in the Miocene Isnotú formation. Subsequent drilling showed the area of richest accumulation to be several kilometers south. In 1924, well MT-1 was completed in the central part of the field as the first Eocene producer. On December 31, 1945, the well had produced from the Eocene a total of 14,656,184 barrels of oil and was still producing at the rate of 200 barrels per day. During 1945 the Mene Grande field produced 12,831,000 barrels of oil and on December 31, 1945, had a cumulative total production of 278,284,000 barrels. The proved area of the field is approximately 10,450 acres. A total of 501 wells had been drilled of which 482 were producers (Fig. 10).

The Shell Company's initial success at Mene Grande was followed by the discoveries in 1915 and 1916 of the Río de Oro and Las Cruces (Tarra) fields southwest of Lake Maracaibo in the District of Colón, Zulia. At Río de Oro 4 wells were drilled of which 3 found limited production in the basal Eocene sediments. The field has never been actively exploited. In the Las Cruces (Tarra) field, 169 wells had been drilled by the end of 1945 of which 144 were producers. Production is from the Eocene and on December 31, 1945, the cumulative total was 58,830,000 barrels. The area of the field is approximately 2,578 acres.

The discovery well of the Bolívar Coastal field was drilled in the La Rosa district in December, 1917, by Venezuelan Oil Concessions, Ltd., a Shell Company subsidiary (Fig. 8). Production was found in the Miocene and up to 1926 all exploitation drilling was confined to this part of the field. In May, 1926, the Mene Grande Oil Company (Gulf Oil Corporation) completed the first commercial well in the Lagunillas district, about 25 kilometers south of the La Rosa area, and in August of the same year production was discovered in the Punta Benitez district. In March, 1928, Lago (Creole) drilled the first well in Tía Juana and in March, 1930, Mene Grande successfully completed a well in the Bachaquero area. These discoveries indicated the presence of commercial accumulation over a distance of approximately 70 kilometers (42.5 miles). During the first 22

OIL FIELD SUMMARY - MARACAIBO BASIN

OIL FIELD SUMMARY - MARACAIBO BASIN

Name of Field	Location State of Zulia Venezuela	Owners and Operators	Discovery Date	Discovery Method	Producing Formations	Type Accumulation	Number of Wells Drilled Prod.	Dry	Total	Grav. Range Deg. A.P.I.	PRODUCTION-BARRELS 1945	Total to Dec. 31, 1945	Proved Acres (Approx.)
BOLIVAR COASTAL	Dist. of Bolivar Lake Maracaibo	Creole Mene Grande Ven.Oil.Conc.	1917	Drilling	Misoa Potreritos Las Flores Icotea La Rosa Lagunillas	Stratigraphic and Structural	3905	95	4000	10-30	196,861,350	2,188,339,129	175,000
LA CONCEPCION	Dist. Maracaibo	Ven.Oil.Conc.	1925	Surf. Geol.	Las Flores	Structural	141	6	147	29-40	1,355,106	29,116,893	1,872
LAS CRUCES (TARRA)	Dist. of Colón	Col.Dev.Co.	1916	Surf. Geol.	Angostura Misoa Pauji	Structural	144	25	169	19-37	3,873,367	58,830,384	2,578
LOS MANUELES	Dist. of Colón	Col.Dev.Co.	1927	Surf. Geol.	Misoa Pauji	Structural	32	4	36	29-37	1,935,283	35,321,610	601
LA PAZ	Dist. Maracaibo	Ven.Oil.Conc.	1925	Surf. Geol.	Capacho La Luna Guasare Potreritos	Structural and Stratigraphic	76	6	82	13-35	8,049,038	19,195,804	2,344
MENE GRANDE	Dist. of Sucre	Caribbean	1914	Surf. Geol.	Misoa Pauji Ienotú	Structural	482	19	501	14-30	12,831,103	278,283,963	10,450
METICK	Dist. of Mara	Orinoco	1929	Surf. Geol.	Potreritos	Structural	3	3	6	21-29	146,022	346,996	154
TETONES (MARA)	Dist. of Mara	Caribbean	1945	Surf. Geol. and Core Drill.	Capacho La Luna	Stratigraphic and Structural	2	1	3	29	1,140,466	1,140,466	250
AMANA (1)	Dist. of Mara	Mene Grande	1928	Surf. Geol.	Potreritos	Structural	1	1	2	31	--	31,362	337
LOS BARROSOS (3)	Dist. of Sucre	Creole	1922	Surf. Geol.	Eocene	Stratigraphic	2	3	5	16-22	--	96,280	--
MISOA (3)	Dist. of Sucre	Creole	1921	Surf. Geol.	Misoa	Structural	2	2	4	15	--	8,000	--
RIO DE ORO (1)	Dist. of Colón	Col.Dev.Co.	1915	Surf. Geol.	Angostura	Structural	3	1	4	26-28	--	54,877	332
TOTUMO (2)	Dist. of Perijá	Creole	1914	Oil Seepages	Basement Erosion Surface	Stratigraphic	11	1	12	19-21	--	149,352	741
							All Others		113				
					TOTAL BASIN (VENEZUELA):		4804	167	5084		216,189,735	2,611,417,116	194,659
					C O L O M B I A								
CARBONERO PETROLEA RIO DE ORO SOCUAVO TRES BOCAS	Barco Concession, Santander del Norte, Colombia	Col.Pet.Co.	1933	Surf. Geol. and Seismograph	Apón Aguardiente La Luna Mito Juan, Catatumbo, Los Cuervos, Barco.	Structural	-	-	-	19-35	5,540,220	23,013,095	** 5,000
					GRAND TOTAL:						221,729,955	2,634,430,211	199,659

(1) Inactive
(2) Abandoned
(3) Depleted
** Estimated

Creole Petroleum Corporation (Standard Oil Company (N.J.))
Venezuelan Oil Concessions, Ltd. (Shell Group)
Colon Development Company (" ")
Caribbean Petroleum Company (" ")
Mene Grande Oil Company (Gulf Oil Corporation)
Orinoco Oil Company (Pure Oil Company)
Colombian Petroleum Company (Socony Vacuum-Texas)

FIG. 10

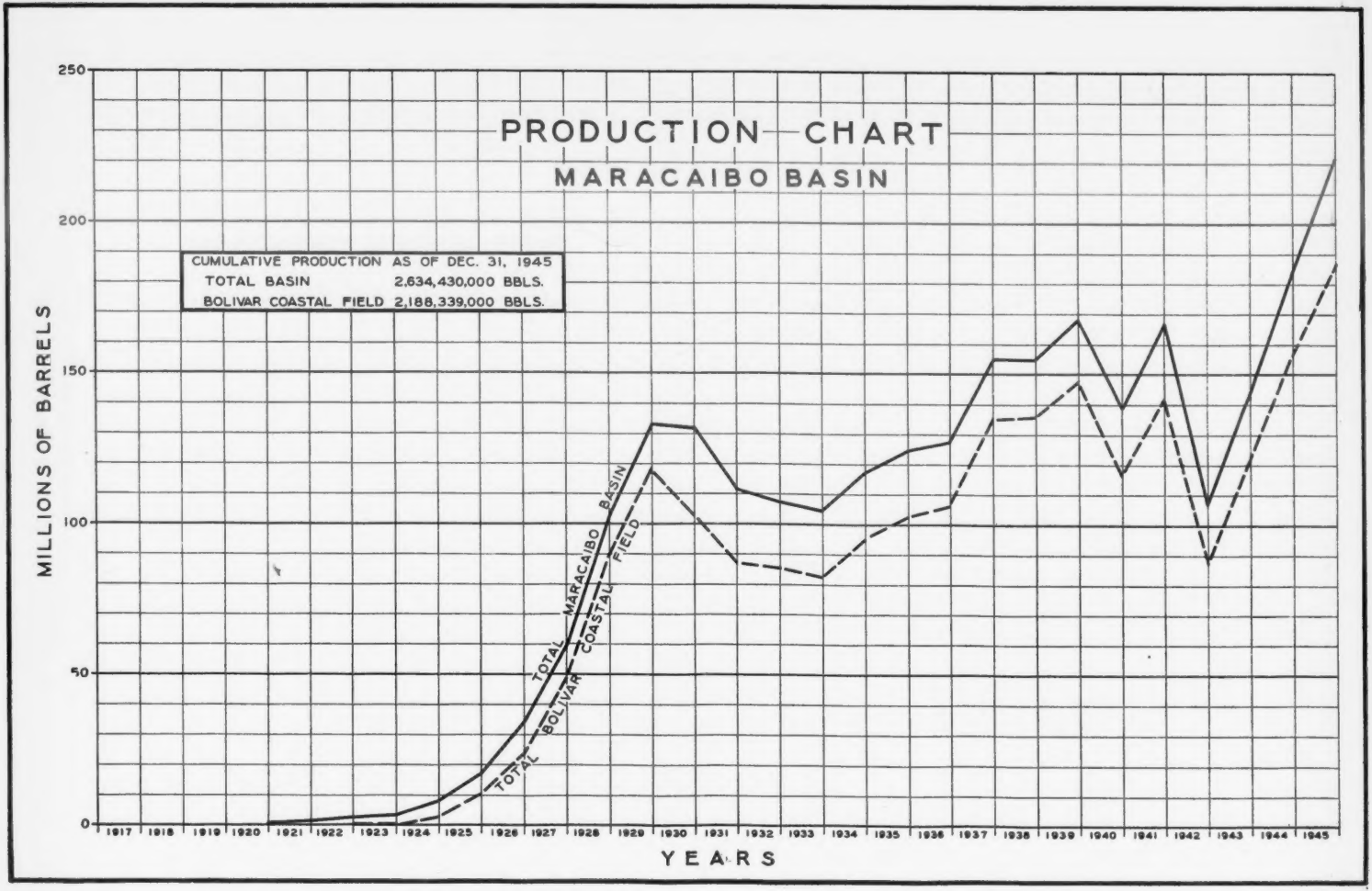

PRODUCTION—CHART
MARACAIBO BASIN
CUMULATIVE PRODUCTION AS OF DEC. 31, 1945
TOTAL BASIN 2,634,430,000 BBLS.
BOLIVAR COASTAL FIELD 2,188,339,000 BBLS.
MILLIONS OF BARRELS
250
200
150
100
50
0
TOTAL MARACAIBO BASIN
TOTAL BOLIVAR COASTAL FIELD
1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945
YEARS

FIG. 11

years of the field's life production was obtained entirely from the post-Eocene sediments. It was the practice to stop drilling when the unconformity was reached. In 1939 Creole completed its well LL-370 as an Eocene producer in the northern Lagunillas district, about 13 kilometers (8 miles) offshore. Since that time the limits of the proved Eocene accumulation have expanded constantly.

During 1945 the Bolívar Coastal field produced a total of 186,861,000 barrels of oil and on December 31, 1945, had a cumulative total production of 2,188,339,000 barrels (Figs. 10 and 11). A total of 4,000 wells had been drilled of which 3,905 were completed as producers. The proved area of the field is approximately 175,000 acres.

The success which attended the early exploratory efforts of the Shell Group soon attracted the attention of others and after the completion of the Bolívar Coastal field discovery well in 1917 the Maracaibo basin witnessed the influx of most of the major American oil companies and many European and American independents. It is estimated that approximately 40 oil companies were represented in western Venezuela between the years 1918 and 1922. Large sums were spent on exploration and wildcat drilling. Most of the companies were unsuccessful and withdrew from the picture. Some sold out to the larger companies or transferred their holdings for a royalty consideration. The Lago Petroleum Corporation (Creole), Shell Group, and Mene Grande Oil Company (Gulf Oil Corporation) became the major operators in the Venezuelan part of the basin. The Orinoco Oil Company (Pure Oil Company) has remained as the owner and operator of the small Netick field in the District of Mara, Zulia.

In 1925 the Shell group discovered the La Concepción and La Paz fields in the District of Maracaibo, Zulia. The former, which produces from the Las Flores and Potreritos formations of the Eocene has a proved area of approximately 1,872 acres. During 1945 the field produced 1,355,000 barrels of oil and at the end of the year had a total cumulative production of 29,119,000 barrels. Of the 147 wells drilled, 141 had been completed as producers.

The La Paz field produced a total of 8,049,000 barrels of oil during 1945 and at the close of the year had a total cumulative production of 19,196,000 barrels. The proved area of the field is approximately 2,344 acres. Of the 82 wells drilled, 76 were completed as producers. Until the latter part of 1944 the production at La Paz was obtained from the Upper Eocene Potreritos and the Paleocene Guasare formations. At that time however, deeper drilling on the east flank of the structure encountered prolific limestone production in the Cretaceous Cogollo and La Luna formations. This new discovery has more than doubled the field's current production. As a matter of fact, the 1945 production amounted to approximately 42 per cent of the cumulative total since the discovery of the field in 1925.

In 1927 the Colón Development Company (Shell Group) discovered the Los Manueles field in the District of Colón, Zulia. The field lies about 15 kilometers (9 miles) north from the Las Cruces (Tarra) field and on the same anticline.

FIG. 11

Production is from the Upper Eocene and during 1945 the field produced a total of 1,933,000 barrels of oil. The cumulative total production as of December 31, 1945 was 35,822,000 barrels. The field has a proved area of about 600 acres. A total of 36 wells have been drilled of which 32 were completed as producers.

The small Netick field of the Orinoco Oil Company (Pure Oil Company) in the District of Mara, Zulia, was discovered in 1929. This field's production is obtained from the Potreritos formation of the Eocene. During 1945 the field produced 146,000 barrels of oil and at the end of the year had a total cumulative production of 347,000 barrels. The proved area of the field is about 154 acres. Of the 6 wells drilled, 3 were completed as producers.

In the early part of 1945 the Caribbean Petroleum Company (Shell Group) discovered the Tetones (Mara) field in the District of Mara, Zulia. The discovery well, DM-2, encountered substantial accumulation in the limestones of the Cretaceous La Luna formation at a depth of about 6,000 feet. At the close of 1945, 3 wells had been drilled of which 2 were completed as producers. The present proved area is roughly 250 acres. During 1945 the field produced a total of 1,140,000 barrels of oil. This is no indication of its potential since the field was shut in during the greater part of the year awaiting the completion of a pipe line to the lake terminal.

In addition to the fields already mentioned, a number of smaller ones have been discovered in the Venezuelan part of the basin. The Los Barrosos and Misoa fields in the District of Sucre, Zulia, were depleted after producing small amounts of oil. The inactive Amana field in the District of Mara, Zulia, has produced 31,000 barrels of oil from the Eocene. The Totumo field in the District of Perijá, Zulia, was abandoned after having produced about 150,000 barrels of oil. This field is interesting in that the accumulation occurs in the fractured and porous zone along the basement surface. The oil, which originated basinward in the Cretaceous and Eocene sediments has moved updip along the unconformity. The field was located a short distance basinward from an area of large seepages where the basement reaches the surface.

During 1945 the production for all fields in the Venezuelan part of the basin amounted to 216,190,000 barrels of oil and the cumulative total to December 31, 1945, was 2,611,417,000 barrels. The proved area was approximately 194,659 acres. A cumulative total of 5,084 wells had been drilled. Of these, 4,971 were field wells, of which 4,804 were completed as producers. A total of 113 non-productive or non-commercial wildcats had been drilled.

The outlet for the oil produced in the Venezuelan part of the basin is by shallow-draft lake tankers to the deep-water terminals of the three major operators. Creole ships its oil to the Dutch Island of Aruba for refining and transshipment. The Shell group has its principal refinery and deep-water terminal on the Dutch Island of Curacao, while the Mene Grande Oil Company has its deep-water terminal at Las Piedras on the Venezuelan Peninsula of Paraguaná.

An 8-inch pipe line connects the Mene Grande field with the lake terminal at

San Lorenzo, a distance of 17 kilometers (11 miles). The Shell Company has a small refinery at this point. The Las Cruces (Tarra) and Los Manueles fields have their lake terminal at La Solita near the mouth of the Río Escalante. An 8-inch pipe line, 125 kilometers (78 miles) long has been laid from the fields to the terminal.

The lake terminal for the La Paz and La Concepción fields is at Punta Piedras near Maracaibo city. A 6-inch pipe line connects La Paz with La Concepción, a distance of 18 kilometers (11 miles) and the combined production of the two fields is then transported through an 8-inch and 5-inch line to Punta Piedras, a distance of 25 kilometers (16 miles).

A 12-inch, 28 kilometer (17 mile) pipe line has been constructed as an outlet for the recently discovered Tetones (Mara) field. The terminal of the line is at Palmarejo on the lake shore.

In the Barco area of eastern Colombia, on the southwest flank of the basin attempts were made to develop commercial production in the Río de Oro field as far back as 1920, but it was not until the discovery of the Petrolea field in 1933 that the Colombian Petroleum Company, then under the control of the Gulf Oil Corporation, began a systematic development of the area. In 1936 a Texas-Socony partnership bought out the Gulf interests and has since discovered fields at Carbonera, Río de Oro, Socuavo, and Tres Bocas. The Petrolea field accounts for most of the production. The development of the area has been discussed in detail by Notestein, Hubman, and Bowler (1944, pp. 1211–15). During 1945 the fields of the Barco Concession produced a total of 5,540,000 barrels of oil and the cumulative production to December 31, 1945 was 23,013,000 barrels. The total proved area of the Concession is estimated at about 5,000 acres. The outlet for the oil from the Barco Concession is by means of a 421 kilometer (252 mile) pipe line whose terminal is at the Colombian port of Coveñas on the Gulf of Morosquillo.

During 1945 the Maracaibo basin produced a total of 221,730,000 barrels of oil. This was almost 69 per cent of Venezuela's total production and between 8 and 9 per cent of the reported world total. The proved area of production is approximately 200,000 acres, or roughly 1.3 per cent of the basin's total area.

As of December 31, 1945, the Maracaibo basin had a cumulative total production of 2,634,430,000 barrels of oil. The remaining proved reserves are estimated in excess of 5,500,000,000 barrels.

Pertinent data concerning the oil fields of the basin are tabulated in Figure 10.

REFERENCES CITED*

BERRY, E. W., 1921. "Tertiary Fossil Plants from Venezuela," *U. S. Nat. Mus. Proc.*, No. 2388, Vol. 59, pp. 553–79; 3 pls., 4 figs.

CASTER, K. E., 1939. "A Devonian Fauna from Colombia," *Bull. Amer. Paleont.*, Vol. 24, No. 83, pp. 1–218; 14 pls.

* Unless otherwise specified, page citations in the text refer to the English edition of *Bol. Geol. y Min.*
For additional references consult HEDBERG, H. D., and F. HEDBERG, 1945. "Bibliografía e indice de la geología de Venezuela," *Revista de Fomento* (Caracas, Venezuela), Año VII, Nos. 58–59, pp. 1–81.

CAUDRI, C. M. B., 1944. "The Larger Foraminifera from San Juan de los Morros, State of Guárico, Venezuela," *Bull. Amer. Paleont.*, Vol. 28, No. 114, pp. 355–412; 5 pls. 2 secs.

CHRIST, P., 1927. "La Coupe géologique le long du chemin de Mucuchachí á Santa Barbara dans les Andes Vénézuéliennes," *Eclog. Geol. Helv.*, Vol. 20, No. 3, pp. 397–414; 4 figs.; abstract by C. C. Zimmerman, 1928, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 11, pp. 1123–25.

CUSHMAN, J. A., AND H. D. HEDBERG, 1941. "Upper Cretaceous Foraminifera from Santander del Norte, Colombia, S. A.," *Contr. Cushman Lab. Foram. Res.*, Vol. 17, Pt. 4, pp. 79–100; 3 pls., 1 fig.

CUSHMAN, J. A., AND H. H. RENZ, 1942. "Eocene, Midway, Foraminifera from Soldado Rock, Trinidad," *Contr. Cushman Lab. Foram. Res.*, Vol. 18, Pt. 1, pp. 1–14, Pls. 1–3.

DOUGLAS, J. G., 1928. "Reserves de agua dulce de la región costanera del Distrito Bolívar, Estado Zulia," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 2, Nos. 2–4, pp. 82–102; 5 pls.; English edition, "Fresh Water Resources in the Bolívar Coastal Area, District of Bolívar, State of Zulia," same bulletin, pp. 84–102.

GARNER, A. H. 1926. "Suggested Nomenclature and Correlation of the Geological Formations in Venezuela, *Amer. Inst. Min. and Met. Eng. Trans.*, pp. 677–84.

GERHARDT, K., 1897–1898. "Beitrag zur Kenntniss der Kreideformation in Venezuela und Peru," *Neues Jahrbuch für Min., Geol. und Päl., Beil.*, Vol. 11, pp. 65–117; 2 pls. 6 figs.

GONZALEZ DE JUANA, C., 1938. Contribución al estudio de la cuenca sedimentaria Zulia-Falcón," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 2, Nos. 2–4, pp. 123–38; 3 pls.; English edition, "A Contribution to the Study of the Zulia-Falcón Sedimentary Basin," same bulletin, pp. 123–40.

HAAS, M. W., AND R. G. HUBMAN, 1937. "Notas sobre la estratigrafía de los campos costaneros del Distrito Bolívar, cuenca de Maracaibo, Venezuela," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 1, Nos. 2–4, pp. 123–64; 3 pls.; English edition, "Notes on the Stratigraphy of the Bolívar Coastal Fields, Maracaibo Basin, Venezuela," same bulletin, pp. 115–55.

HALSE, G. W., 1937. "La estratigrafía del occidente del Distrito Buchivacoa, Estado Falcón, Venezuela," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 1, Nos. 2–4; pp. 183–93; 3 pls.; English edition. "The Stratigraphy of West Buchivacoa, Venezuela," same bulletin, pp. 175–84.

HEDBERG, H. D. 1931. "Cretaceous Limestone as Petroleum Source Rock in Northwestern Venezuela," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 3, pp. 229–44; 8 figs.

———, 1937. "Stratigraphy of the Río Querecual Section of Northeastern Venezeula," *Bull. Geol. Soc. America*, Vol. 48, No. 12, pp. 1971–2024; 2 figs., 9 pls.; abstract, *Geol. Soc. America Proc. 1936*, pp. 78–79.

———, 1937. "Estratigrafía de la sección del Río Querecual en el noreste de Anzoategui, Venezuela," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 1, Nos. 2–4, pp. 253–65; 3 pls.; English edition, "Stratigraphy of the Río Querecual Section of Northeastern Venezuela," same bulletin, pp. 239–50.

HEDBERG, H. D., AND L. C. SASS, 1937. "Sinopsis de las formaciones geológicas de la parte occidental de la cuenca de Maracaibo, Venezuela," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 1, Nos. 2–4, pp. 77–120; 2 pls; English edition, "Synopsis of the Geologic Formations of the Western Part of the Maracaibo Basin, Venezuela," same bulletin, pp. 73–112.

HETTNER, A., 1892. "Die Kordillere von Bogotá," *Peterm. Mitteil., Erg.*, Vol. 22, No. 104, pp. 1–131.

HODSON, F., 1926. "Venezuelan and Caribbean Turritellas," *Bull. Amer. Paleont.*, Vol. 11, No. 45, pp. 171–220, Pls. 5–34.

HODSON, F., H. K. HODSON, AND G. D. HARRIS, 1927. "Some Venezuelan and Caribbean Mollusks," *Bull. Amer. Paleont.*, Vol. 13, No. 49, pp. 1–160, Pls. 1–140.

HODSON, F., AND H. K. HODSON, 1931. "Some Venezuelan Mollusks," *Bull. Amer. Paleont.*, Vol. 16, pp. 1–132, Pls. 1–36.

HODSON, H. K., 1926. "Foraminifera from Venezuela and Trinidad," *Bull. Amer. Paleont.*, Vol. 12, No. 47, pp. 1–46, Pls. 1–8.

HOFFMEISTER, W. S., 1938. "Aspecto y división en zonas de la fauna de moluscos en las formaciones La Rosa y Lagunillas, campos costaneros de Bolívar, Venezuela," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 2, Nos. 2–4, pp. 103–22; English edition, "Aspect and Zonation of the Molluscan Fauna in the La Rosa and Lagunillas Formations, Bolívar Coastal Fields, Venezuela," same bulletin, pp. 103–22.

KEHRER, L., 1937. "Algunas observaciones en capas Cretáceas y Pre-cretáceas de las partes suroeste y central de Venezuela," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 1, Nos. 2–4, pp. 49–73; 4 figs., 5 pls.; English edition, "Some Observations on Cretaceous and Pre-Cretaceous Beds in the Southwestern and North-Central Parts of Venezuela," same bulletin, pp. 47–70.

———, 1938. "Algunas observaciones sobre la estratigrafía en el Estado Táchira, Venezuela," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 2, Nos. 2–4, pp. 44–56; English edition, "Some Observations on the Stratigraphy in the States of Táchira and Mérida, S. W. Venezuela," same bulletin, pp. 44–55.

KÜNDIG, E., 1938. "Las rocas Pre-cretáceas de los Andes centrales de Venezuela con algunas obser-

vaciones sobre su tectónica," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 2, Nos. 2–4, pp. 21–43; 1 pl.; English edition, "The Pre-Cretaceous Rocks of the Central Venezuelan Andes with some Remarks about the Tectonics," same bulletin, pp. 21–43.

LIDDLE, R. A., 1928. *The Geology of Venezuela and Trinidad.* 552 pp. J. P. MacGowan, Fort Worth, Texas.

LIDDLE, R. A., G. D. HARRIS, AND J. W. WELLS, 1943. "The Río Cachirí Section in the Sierra de Perijá, Venezuela," *Bull. Amer. Paleont.*, Vol. 27, No. 108, pp. 273–375; 10 pls., 2 figs., 1 map.

MACKENZIE, A. N., 1937. "Sección geológica de la región de Barinas, Distritos Barinas, Bolívar y Obispos del Estado Barinas, Venezuela," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 1, Nos. 2–4, pp. 269–83; 3 pls.; English edition, "Geologic Section of the Region around Barinas, Districts of Barinas, Bolívar and Obispos, State of Barinas, Venezuela," same bulletin, pp. 253–66.

NOTESTEIN, F. B., C. W. HUBMAN, AND J. W. BOWLER, 1944. "Geology of the Barco Concession, Republic of Colombia, South America," *Bull. Geol. Soc. America*, Vol. 55, No. 10, pp. 1165–1216; 6 pls., 12 figs.

NUTTALL, W. L. F., 1935. "Upper Eocene Foraminifera from Venezuela," *Jour. Paleont.*, Vol. 9, No. 2, pp. 121–31; 2 pls.

OPPENHEIM, V., 1937. "Contribución a la geología de los Andes venezolanos," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 1, Nos. 2–4, pp. 23–45; 2 figs., 1 pl.; English edition, "Contribution to the Geology of the Venezuelan Andes," same bulletin, pp. 23–43.

RUTSCH, R., 1936. "Die stratigraphische Bedeutung der *Venericardia planicosta* und ihrer Verwandten," Part IV of "Beiträge zur Kenntnis tropisch-amerikanischer Tertiärmollusken," *Eclog. Geol. Helv.*, Vol. 29, No. 1, pp. 151–86; 1 pl., 1 fig.

SCHAUB, H. P., 1944. "Fusulinids in La Quinta Formation, Venezuela," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 28, No. 11, pp. 1642–44; 1 fig.

SCHUCHERT, C., 1935. *Historical Geology of the Antillean-Caribbean Region*, John Wiley and Sons, Inc. 811 pp.

SENN, A., 1935. "Die stratigraphische Verbreitung der tertiären Orbitoiden mit spezieller Berücksichtigung ihres Vorkommens in Nord-Venezuela und Nord-Marokko," *Eclog. Geol. Helv.*, Vol. 28, No. 1, pp. 51–113; supplement, pp. 369–73; 2 pls., 1 fig.

SIEVERS, W., 1888. "Die Cordillere von Mérida, nebst Bemerkungen über das Karibische Gebirge," *Geogr. Abhandl.* (Penck), Vol. 3, No. 1. 238 pp. ,1 map, 15 prof.

TASH, G. E., 1937. "Estratigrafía y paleontología de Mene Grande y sus cercanías," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 1, Nos. 2–4, pp. 167–80; English edition, same bulletin, pp. 160–72.

TOMALIN, W. G. C., 1938. "La estratigrafía de las formaciones Cretáceas en las cercanías del valle del Río Carache, Estado Trujillo," *Bol. Geol. y Min.* (Caracas, Venezuela), Vol. 2, Nos. 2–4, pp. 11–20; English edition, "The Stratigraphy of the Cretaceous Formations in the Neighbourhood of the Río Carache Valley, State of Trujillo," same bulletin, pp. 11–20.

TRÜMPY, D., 1943. "Pre-Cretaceous of Colombia," *Bull. Geol. Soc. America*, Vol. 54, No. 9, pp. 1281–1304; 1 pl., 6 figs.

VAUGHAN, T. W., 1945. "American Old and Middle Tertiary Larger Foraminifera and Corals; Part I, American Paleocene and Eocene Larger Foraminifera," *Geol. Soc. America Mem. 9*, pp. 1–175, Pls. 1–46.

VAUGHAN, T. W., AND W. S. COLE, 1941. "Preliminary Report on the Cretaceous and Tertiary Larger Foraminifera of Trinidad, British West Indies," *Geol. Soc. America Spec. Paper 30*, pp. 1–137, Pls. 1–46; 2 figs.

WEISBORD, N. E., 1926. "Venezuelan Devonian Fossils," *Bull. Amer. Paleont.*, Vol. 11, No. 46, pp. 223–68; 7 pls.

WILLISTON, S. H., AND C. R. NICHOLS, 1928. Review of "The Geology of Venezuela and Trinidad," by R. A. Liddle, *Bull. Amer. Assoc. Petrol. Geol.* Vol. 12, No. 4, pp. 445–51.

APPENDIX

A. N. DUSENBURY, JR.

VENERICARDIA (VENERICOR) TOASENSIS DUSENBURY N. SP.

Venericardia planicosta Liddle, 1928, "The Geology of Venezuela and Trinidad," pp. 183–86. Not Lamarck, 1806, Middle Eocene of France.

Venericardia parinensis Rutsch, 1936, "Die stratigraphische Bedeutung der *Venericardia planicosta* und ihrer Verwandten," Part 4 of "Beiträge zur Kenntnis tropisch-amerikanischer Tertiärmollusken," *Eclogae Geologiace Helvetiae*, Vol. 29, No. 1, pp. 152–86. Not *Venericardia planicosta* var. *parinensis* Olsson, 1928, Middle Eocene of Perú.

Venericardia parinensis Hedberg and Sass, 1937, "Sinopsis de las Formaciones geologícas

de la Parte occidental de la Cuenca de Maracaibo," *Boletin de Geología, y Minería*, Vol. 1, Nos. 2, 3 y 4, p. 93.

Shell small for the genus, thick, massive, trigonocordate, moderately inflated. Umbones small, prosogyrate, tapering at an angle varying between 90° and 102°, situated about one fourth of the total length of the shell back from the anterior end, marked by a rounded but distinct ridge which runs down to the posterior ventral angle of the margin. Lunule subtriangular, deep and wide, ligament area prominent, no defined escutcheon. Anterior dorsal margin moderately concave, anterior end very broadly convex, ventral margin upcurved anteriorly but becoming almost straight posteriorly with a rounded posterior ventral angle, posterior end almost vertically truncate, rounding into an increasingly convex posterior dorsal margin. External sculpture consisting of 23 radial ribs crossed by close concentric growth lines. Of the radial ribs, 16 are relatively wide and occupy the anterior and medial portions of the valve back as far as the rounded umbonal ridge; the next 3 are much narrower and weaker, and lie in a distinct but shallow trough, immediately posterior to the umbonal ridge and extending from the umbo toward the truncate posterior margin; the next radial rib, marking the posterior rim of the trough, is somewhat stronger; the final 3 posterior ribs are the weakest and most obscure of all. Near the umbo the ribs are narrow, sharply crested and slightly crenulate, separated by V-shaped interspaces; toward the center of the shell they become first round-crested with loss of all crenulation, and then flat-crested, broadening continually and separated by narrow, linear grooves of constant width; from the center to the ventral margin of the shell the ribs die out and disappear beneath the crowded concentric growth lines, which gradually become stronger until they form the sole ornamentation. Hinge plate relatively low and wide for the genus, much thinner and weaker than the umbonal part of the valve. Teeth small, heavy, strongly oblique. Dentition of right valve consisting of a small, thin, laminar, nearly obsolete anterior cardinal obliquely set to the forward edge of the hinge plate at an angle of about 30°, forming a lip for the anteroventral rim of the cuneo-ovate anterior socket; a large, heavy, gently curved, cornutiform medial cardinal, oblique to the forward edge of the hinge plate between the angles of 45° and 60° approximately; and an elongate, laminar, slightly curved posterior cardinal produced along the inner margin of the narrow nymph and separated from the medial cardinal by the elongate, striate, slightly curved, cornutiform posterior socket. Dentition of left valve observed only in a single much weathered specimen; posterior cardinal strong, its posteroventral projection creating a small bulge in the otherwise almost straight ventral margin of the hinge plate. Muscle scars and pallial line not observed in material at hand. Maximum dimensions of collected specimens: Height 46 mm., width (of another specimen) 51 mm., neither specimen complete.

Type locality.—Serial sample locality 13,002 of Creole Petroleum Corporation, about 600 feet northwest of Las Playitas village, north shore of Toas Island, District of Mara, State of Zulia, Venezuela.

Distribution.—Guasare formation of Upper Paleocene (Thanetian) age; Toas Island, Río Cachirí, Caño Frío, Caño Indio Negro, and Río Carache sections. Most abundant in the massive limestone beds in the basal part of the formation. Also, according to Rutsch, Soldado formation of Upper Plaeocene age, Soldado Rock and Marac Quarry Trinidad.

Remarks.—Since the medial cardinal tooth of the right valve is curved, instead of straight, the species belongs in the section *Venericor* s.s., rather than in the section *Leuroactis*.

Venericardia toasensis differs from *V. planicosta* in the smaller size, the more prosogyrate umbones, the smaller number of radial ribs, which are overrun by the growth lines near the center of the shell instead of near the ventral margin, in the lower hinge plate and the less curved, more oblique teeth. From *V. samanensis* Olsson, it differs in smaller size, proportionately greater width, truncate posterior end, the shallow, trough-shaped

depression behind the umbonal ridge, and the smaller, weaker hinge, lower hinge plate and less curved, more oblique teeth. It varies from *V. parinensis* Olsson in smaller size, more prosogyrate and less swollen umbones, the shallow, trough-shaped depression behind the umbonal ridge, the narrow radial ribs posterior to the umbonal ridge, the lower hinge plate, more oblique teeth and the less crowded anterior cardinal in the right valve.

The exterior of *Venericardia toasensis* is more like that of *V. parinensis* Olsson than that of any other described species, a fact which possibly indciates the ancestral relationship of the former to the latter. On the other hand, the dentition of *V. toasensis* most nearly resembles that of *V. bashiplata* Gardner and Bowles, 1939, of the upper Wilcox of Alabama, although the external appearance is quite dissimilar.

Type specimens deposited at Paleontological Research Institute, Ithaca, New York.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 10 (OCTOBER, 1946), PP. 1742-1746, 9 FIGS.

ALGAE REEFS IN CAP ROCK OF OGALLALA FORMATION ON LLANO ESTACADO PLATEAU, NEW MEXICO AND TEXAS[1]

W. ARMSTRONG PRICE,[2] MAXIM K. ELIAS,[3] AND JOHN C. FRYE[4]
Corpus Christi, Texas; Lincoln, Nebraska; and Lawrence, Kansas

ABSTRACT

Discovery is announced of reef bodies in the Ogallala cap rock on the Llano Estacado Plateau of New Mexico and Texas, similar to those previously described by Elias from a limestone in the same position in Kansas and elsewhere on the Northern High Plains.

The characteristic concretionary structure of the reefs is widely but not universally repeated—with and without observed reef bodies—in the upper part of the Ogallala cap rock, and in post-Ogallala limestone cap rocks of basin deposits of the plateau and of the Mescalero pediment between the plateau and Pecos River.

A syngenetic origin for many of the banded concretionary bodies is preferred, while the formerly advanced post-depositional hypothesis of Price may apply to others.

The conclusions here briefly presented were formed by the writers during a field conference on the Ogallala and Quaternary of the Llano Estacado Plateau (Figs. 1, 2, and 3) in New Mexico and Texas, conducted by Price in August, 1945.[5]

The views here expressed do not necessarily reflect the opinions of the other members of the conference party, listed in the note in "*Science*"[6] and in the Association *Bulletin*.[7]

The Llano Estacado plateau (Fig. 1) is an erosional remnant of alluvial plains which formerly stretched from the western mountains in New Mexico to the Central Lowland which includes the Mississippi Valley and the Gulf of Mexico.[8] It is capped by the Pliocene Ogallala formation, of sandy alluvium. This is itself capped by a 10- to 30-foot zone of irregular calcareous cementation known locally as the cap rock or "caliche" limestone. The top of the cap rock is believed to be a depositional surface which has developed a youthful solution karst of smooth-sided, bowl-shaped basins. Streams have sunk widely separated narrow courses across it. These become deep canyons on the downslope, eastern side. The surface between the canyons is little eroded, having interior-basin drainage.

[1] Manuscript received, March 18, 1946. A preliminary paper under this title was read at the Pittsburgh meeting of the Geological Society of America, December 29, 1945. Abstract appeared in *Bull. Geol. Soc. America*, Vol. 56, No. 12, Pt. 2 (December, 1945), p. 1192.

[2] Consulting geologist, Corpus Christi, Texas.

[3] Paleontologist, Nebraska Geological Survey, Lincoln, Nebraska.

[4] Assistant State geologist of Kansas, Lawrence, Kansas.

[5] W. Armstrong Price, "The Pliocene Ogallala Formation and Associated Quaternary Deposits," *Science*, N.S., Vol. 102, No. 2655 (November 16, 1945), p. 501.

[6] *Ibid.*

[7] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 9 (September, 1945), p. 1374.

[8] Fenneman, *Physiography of the Western United States*. McGraw-Hill Book Company (1931). 534 pp.

In the early to middle Recent[9] dune sand covered the plateau. This sand has been stabilized by vegetation, has developed soils and now has a rolling surface without distinctive dune forms over much of its eastern half. The western third or fourth of the plateau has been largely stripped of the dune sand by deflation. Some areas of active or lightly stabilized dunes of modern and late Recent time occur

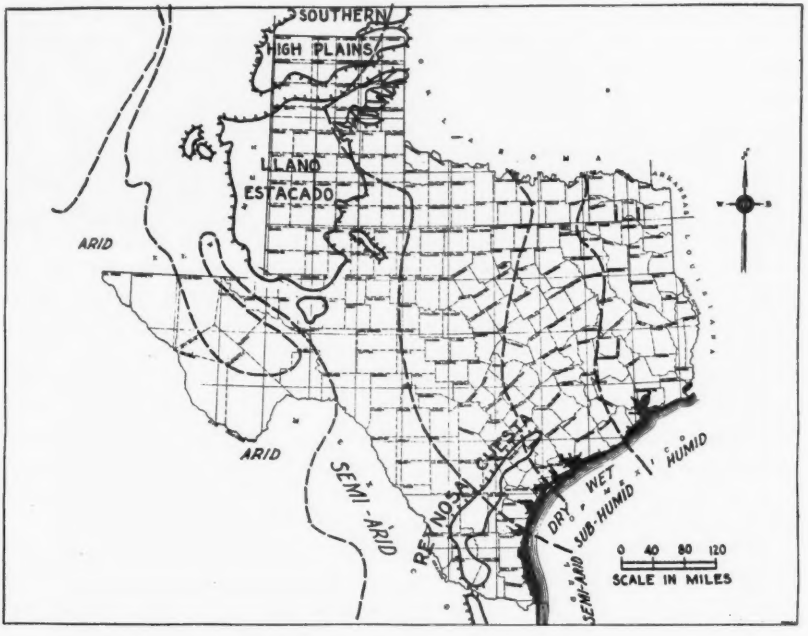


FIG. 1.—Llano Estacado of Texas and New Mexico, its relation to the Southern High Plains, and its climate. The tongue of arid climate running northwest and southeast and lying west of the High Plains follows the valley of Rio Grande. A shorter tongue of arid climate follows the Pecos, between Rio Grande and the Llano Estacado. The escarpment is continuous except at the south, where it abuts against the Edwards Plateau.

on it. It is thought possible that dune sand was also formed on or blown on the plateau at earlier times, probably during the Pleistocene, but, if so, the earlier sands have not been recognized.

The surface of the Llano Estacado has not been peneplaned, but represents modified Pliocene and Recent depositional surfaces. The plateau has been isolated on the west and on the east by stream erosion. On the east, many streams head against it and it is actively undergoing erosion under a sub-humid climatic

[9] W. Armstrong Price, "Greater American Deserts," *Proc. and Trans. Texas Acad. Science*, Vol. 27 (1944), pp. 163–70.

regime (Fig. 1). Quaternary terraces are found against it on the eastern side. The western slopes, beginning with an escarpment, have been cut into a concave erosional and depositional surface under arid and semi-arid regimes. This surface slopes toward the Pecos River and its terraces and has been called the Mescalero pediment by Morgan and Sayre.[10] Pleistocene deposits beneath the Mescalero surface, in some cases filling deep basins, have been named the Gatuña formation by W.B. Lang[11]

At the north the Llano Estacado is isolated from other remnants of the High Plains by the broad, deeply entrenched valley of Canadian River, with its terraces.

The Ogallala of the plateau is everywhere capped by a sandy "caliche" limestone with irregular bedding and cementation (Fig. 4). Field observations abundantly confirm the occurrence in this cap rock of calcareous algal reef-bodies of oval and tabular forms known, respectively, as bioherms and biostromes. Elias had previously announced[12] the presence of such reefs with similar lithologic characteristics in the capping limestone of the Ogallala in western Kansas, and also in western Nebraska, where this unit has been placed at the top of the Kimball formation of the Ogallala group.[13] The algae and associated lithologic characteristics have previously been recognized in it by Elias in Nebraska, Kansas, and Oklahoma on the High Plains, and are here reported from Texas and New Mexico.

The best developed reef-bodies noted on the 1945 conference trip were about 4 by 8 feet across and 3 feet thick (Fig. 5). They were found at the top of the Ogallala cap rock at locality T-7. Others were as long, but flatter, as in the top of the cap rock of what seems to be an outlier mesa of the Ogallala at locality T-9.

The large reef-bodies recognized were more densely cemented than the enclosing limestone and had been left as rejects in caliche quarries. They occur chiefly at and near the top of the bed. The upper part of the cap rock and locally other parts contain abundant banded bodies or concretions[14] which vary in size from oölites to pisolites and larger bodies, including tabular, oval to rounded forms (Fig. 6).

In the bioherm there may be prominent zones an inch or two thick of crenulated laminated limestone enclosing large masses of concretionary sandy limestone (Fig. 7). Angular inclusions occur and these are commonly also enclosed by

[10] A. M. Morgan and A. N. Sayre, "Geology and Ground Water," Pt. II, Repts. Pecos River; Joint Investigation, National Resources Planning Board (Washington, D. C., 1942), p. 35.

[11] T. W. Robinson, and W. B. Lang, "Geology and Ground-Water Conditions of the Pecos Valley in the Vicinity of Laguna Grande de la Sal, New Mexico, with Special Reference to the Salt Content of the River Water," *New Mexico State Engineer 12th and 13th Bienn. Rept. for 1934–1938* (1939), pp. 84–85.

[12] M. K. Elias, "The Geology of Wallace County, Kansas," *Geol. Survey Kansas Bull. 18* (1931). 254 pp. See especially pp. 136–40 and Pls. 20–23.

[13] A. L. Lugn, "Classification of the Tertiary System in Nebraska," *Bull. Geol. Soc. America*, Vol. 50, No. 8 (August, 1939), pp. 1245–76.

[14] M. K. Elias, *op. cit.*, pp. 163–70.

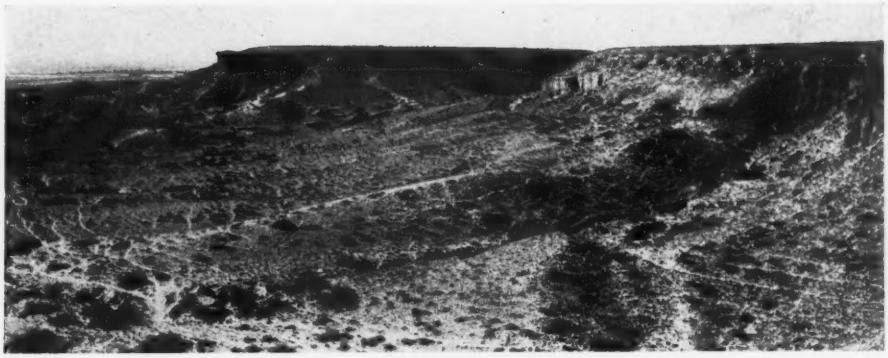


FIG. 2.—L-10 ("L" numbers are localities of W. A. Price's Llano Estacado list not visited by the conference party). Western escarpment of Llano Estacado in Ogallala formation at first projecting point north of Maljamar, Lea County, New Mexico. Cap rock over "palisade sands" with columnar jointing. Photograph by Price.

FIG. 3.—T-3 ("T" numbers are Price's localities visited by the conference party and refer to M. K. Elias' "conference list" of Texas localities). Section of Ogallala formation in Llano Estacado on north wall, Tierra Blanca Creek, 3.5 miles south-southwest of town of Canyon, Randall County, Texas. Center of NE. ¼ of Sec. 59. Ogallala, 108 feet thick, resting on Triassic red and green shale not shown in photograph. Cap rock rests on "palisade sands" showing several ledges, the lower topped by a zone of silicification with gravel. Photograph by Frye.

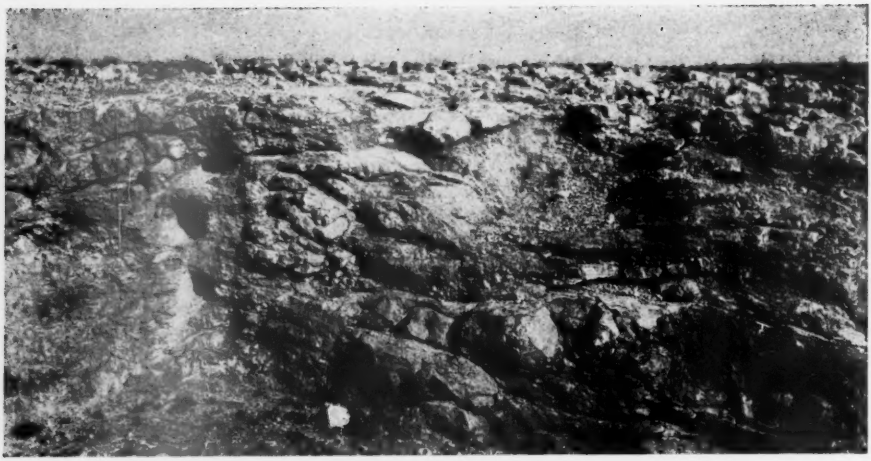


FIG. 4.—L-6. Irregular stratification in Ogallala cap rock. Large lens-shaped body may be a concretion. Western escarpment of Llano Estacado in Ogallala formation where road from Hagerman reaches scarp, Chaves County, New Mexico. Photograph by Price.

FIG. 5.—T-7. Oval reef-like mass or bioherm from top of Ogallala cap rock. Size, 3×4×8 feet. Quarry on north rim of Portales Valley, 4 miles east of town of Muleshoe, Bailey County, Texas, 200 yards south of Plainview Highway. Section in cap rock from reef-bearing limestone above to porcellanous and internally folded limestone below. Indefinite courses of "Blackwater Draw" lie both north and south of quarry. Photograph by Price.

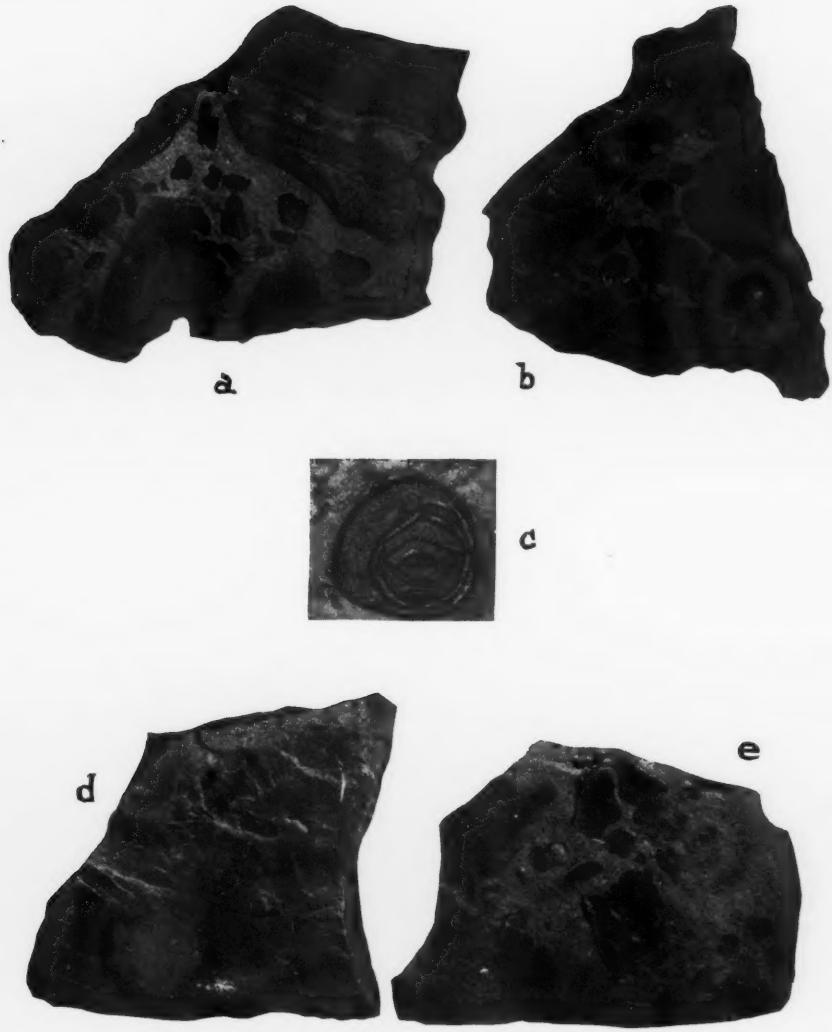


FIG. 6.—Concretions and inclusions in Ogallala cap rock, half natural size.

a, b: Fragments of large concretions showing outer envelope with inclusions of sandy limestone bodies enclosed by bands of amorphous calcium carbonate colored by red and black manganese oxides. Matrix, gray sandy limestone. Locality T-11. Collections from top of cap rock of Ogallala near Caprock village, 4 miles east of western escarpment of Llano Estacado and Clark's Gap on Roswell to Tatum Highway. Photographs by Price.

c: Pisolite, 9/7 natural size, from top of cap, showing two generations of growth separated by fracturing. Locality T-9. Outlier of Ogallala (?) forms mesa 18 miles west of western scarp of Llano Estacado, 2 miles south of village of Elkins, Chaves, County, New Mexico, and about ¼ mile north of Railroad Mountain igneous dyke, the northernmost of two mapped by Darton. Quarry shows about 40 feet of Ogallala (?) on red and purple shales of Triassic. Photograph by Price.

d, e: Non-concretionary silicified basal Ogallala cap rock. Angular fragments of same in *e*. Dark red sandstone pebble and mass of white, opaline silica with scalloped outline suggesting replacement. Locality L-4. Quarry in cap rock of Ogallala at southwest end of basin of Bull Lake, Lamb County, Texas, west of Littlefield. Specimens from siliceous basal portion. Photograph by Price.

FIG. 7.—Detail of surface of bioherm of Figure 5. Six-inch rule shows scale. Locality T-7.

FIG. 8. (*right*)—T-16. A few inches of concretionary capping limestone on Gatuña formation. High cut on Carlsbad to Hobbs Highway, scarp of Nimenim Ridge. About 20 feet of Gatuña formation exposed with thin concretionary limestone cap rock and distortion due to internal expansion in Gatuña. Approximate locality, Sec. 36, T. 20 S., R. 30 E., Eddy County, New Mexico. Photograph by Price.

FIG. 9.—T-26. Internal compression folding, thrust faulting, and fissuring in white, porcellaneous Ogallala cap rock, passing into greenish clay shale at base just below bottom of photograph. Quarry in Ogallala cap rock, north bank of Yellowhouse Creek Valley on College Avenue, Lubbock, Texas. Possibly in eastern extension of Portales Valley, but topographic depression here seems confined to thinning of eolian mantle above cap rock. Photograph by Price.

thin bands of calcium carbonate with light reddish, brown, or black manganese oxides.

Banded and concretionary structure like that of the bioherms, although not observed at all exposures, and with or without reef structure being noted, is widely repeated in the topmost part of the limestone over the plateau, being confined in some places to a mere inch or two, at others occurring also in lower beds of the cap rock.[15] Similarly banded and concretionary structure, not accompanied by large bioherms, was found more sparingly developed at the tops of "caliche" limestone cap rocks of post-Ogallala Quaternary deposits in large depressions of the plateau and on its flanks toward Pecos River. The most widespread of these limestone-capped deposits seen on the conference trip is the Quaternary Gatuña formation lying on the Mescalero pediment[16] (Fig. 8). This formation was studied in the field through the courtesy of Ronald K. DeFord and his associate W. A. Waldschmidt of the Argo Oil Corporation.[17] The "caliche" limestone of the Gatuña formation is thought by Robinson, Lang, and DeFord to be younger than the Gatuña.

Price had formerly attributed the concretionary "pisolitic" structure of the Ogallala cap rock on the Llano Estacado[18] to post-depositional concretionary banding of inorganic origin formed by descending post-depositional solutions depositing material around internally fractured fragments of the limestone. More detailed examination of these "cap-rock" limestones indicates that this hypothesis will not account for the lenticular reef masses and accompanying concretionary structure, but may be applicable to (1) some, but not all, secondary limestones of the region where a porous "caliche" cement unites coarse surface rubble including stream gravel, rubble and gravel being in many cases enclosed by concentric bands of calcium carbonate or manganese oxide or both; (2) encrustations of calcium carbonate, manganese oxide or silica on solution surfaces and on the walls of other openings, such as the numerous fracture and slippage surfaces in internally folded portions of the cap rock (Fig. 9) and as calcareous linings of small solution funnels and openings interpreted by Frye as fossil animal burrows.

Some of the observed internal fragmentation of the cap rock, especially that followed by concretionary growth, is syngenetic in origin, probably being caused by the breaking-off of masses from the growing algal reef. A fragment with a crenulated edge, possibly formed in this way is shown in Figure 6a, in the lower

[15] Concretionary structure has been recorded by most writers on the plateau since W. F. Cummins, *3rd Ann. Rept., Geol. Survey of Texas* (1892).

[16] T. W. Robinson and W. B. Lang, *op. cit.*, pp. 79–86. A. M. Morgan and A. N. Sayre, *op. cit.*, p. 35.

[17] Midland, Texas.

[18] W. Armstrong Price, "The Clovis Site: Regional Physiography and Geology," *American Antiquity*, Vol. 9, No. 4 (April, 1944), pp. 401–17. The geomorphology of the plateau was recently briefly described in:

———, "Greater American Deserts," *Proc. and Trans. Texas Acad. Science*, Vol. 27 (1944), pp. 163–70.

left-hand part of the specimen. Internal fragmentation observed especially in a white porcellaneous member containing some clay which is present in some localities, as at T-7 and T-26, is interpreted as having been produced during weathering mainly by expansion causing strong compression within the body of the rock.[19] This fragmentation occurred probably after the clayey member, usually basal in position, had been partly indurated, but it is not demonstrated that the fragments so produced have become enclosed by pisolitic envelopes within the body of the rock, although in places they have been recemented by calcium carbonate or have received coatings of silica and manganese oxide at the outcrop. Specimens of recemented, non-concretionary, calcareous and siliceous breccia have been collected by Price from numerous outcrops of the Ogallala and other "caliche" cap rocks of this region. The breccia is silicified in basal positions in the bed (Fig. 6, d, e,) or in white or very pale pink rock in upper layers.

The irregularly banded and concretionary structure is most characteristic in the pale tan, pinkish or grayish white, somewhat compact, thin-bedded and sandy limestone strata in the upper part or at the top of the cap rock. The middle portion of the Ogallala cap rock is characteristically a sandy member with less cementation and more porous cement than in the upper and lower parts. Concretionary structure may occur in this part of the bed in thin members.

The term "cap rock" is advisedly used for an unnamed limestone forming the uppermost bed of the Ogallala on the Llano Estacado proper. It is not applied here to lower calcareous or siliceous zones in the Ogallala which happen to hold up outlier mesas. Since the late geologic history of the plateau does not indicate any periods of erosion strong enough to destroy a 10-foot to 30-foot stratum such as this, with its calcareous cementation, except locally, and since there seems to be everywhere on the plateau such a capping limestone of similar lithology, it is believed that we are dealing with a single recognizable capping bed in the Ogallala.

The question of whether the envelopes of calcium carbonate and manganese oxide enclosing fragments of the cap rock material have been produced (a) by the agency of algae, (b) by syngenetic, non-organic chemical precipitation, or (c) by later internal chemical aggregation has not yet been answered. At the Odessa Meteor Crater, Ector County, Texas, and north of Stanton, in Martin County, Texas, "caliche" types of cap rock on Cretaceous limestone contain reworked *Gryphaeas* enclosed in similar concretionary envelopes. In other places in this region rubble of angular pieces of pre-Tertiary rocks with gravel is reported by Glenn Evans, of the Bureau of Economic Geology, University of Texas, to be encrusted with similar concretionary envelopes of calcium carbonate and manganese oxide. These occurrences suggest syngenetic tuffaceous deposition around rubble and gravel on a flood-washed surface or in a stream bed.

[19] W. Armstrong Price, "Caliche and Pseudo-Anticlines," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 6 (September, 1925), pp. 1,009–17.
W. G. Woolnough, "Pseudo-Tectonic Structures," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 9 (September, 1933), pp. 1098–1106.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 10 (OCTOBER, 1946), PP. 1747-1755, 3 FIGS.

KINDERHOOK DOLOMITE OF SEDGWICK COUNTY, KANSAS[1]

W. A. VER WIEBE[2]
Wichita, Kansas

One of the producing formations in Kansas is a dolomite found in the Goodrich pool of Sedgwick County. The first well in this pool was the Goodrich No 1. of the Marland Oil Company, completed on December 3, 1928. It flowed an estimated 7,000 barrels of oil from the Mississippian "chat" at 3,010 to 3,020 feet. A later well on the Westerfield farm found the "chat" barren and was drilled down to a dolomite at 3,326 feet which was proved to be capable of producing 90 barrels of oil per day. Subsequently, a considerable number of other wells were drilled in the field and five of them produced oil from the dolomite which had been found in the Westerfield well. In describing this pool, Edward A. Koester[3] called the dolomite producing in the field well "Misener dolomite." The reason for choosing this name was the fact that the dolomite occurs in many wells immediately beneath a very thin sandstone generally called the "Misener" sandstone.

To January 1, 1938, the Goodrich pool had produced nearly 2 million barrels of oil. This good recovery, coupled with the fact that three different formations produced oil in the pool led to extensive wildcatting in every direction from the pool. Most of the wells drilled in the adjacent townships that are deep enough to penetrate the dolomite found in the Westerfield well, are listed in Table I.

In Table I the Westerfield dolomite is called simply "Dolomite" and all pertinent data with reference to it as well as to overlying and underlying rocks are given. It may be noted that the thickness of the overlying Kinderhook shale is approximately 75 feet in and around the Goodrich pool which centers in Sec. 16, T. 25 S., R. 1 E.

All students of Kansas stratigraphy agree that the shale above the dolomite is definitely part of the Kinderhook formation although it is often called the Chattanooga shale. The age of the shale below the dolomite, however, has not been definitely established. Therefore, the age of the dolomite is also questionable. It is the purpose of the writer to prove that this shale is also a part of the Kinderhook sequence. If that fact can be established the dolomite must be Kinderhook in age and belong to the Mississippian sequence of central Kansas. At present the dolomite is called by various names among which are "Misener dolomite," Viola, and Hunton. Perhaps the name Hunton is most frequently applied to it by the micro-lithologists of Kansas.

NATURE OF UPPER SHALE

The upper shale in the Goodrich area is a black shale almost exclusively. The higher beds are characterized by layers which are dull, smooth, and non-mica-

[1] Manuscript received, January 27, 1946.

[2] University of Wichita.

[3] Edward A. Koester, *State Geol. Survey of Kansas Mineral Resources Cir. 3* (1934), p. 63.

ceous. The rock is somewhat fissile and splintery. A broken surface shows a dark brownish black color. Lower, the layers become more micaceous, although the mica flakes are extremely small. The rock takes on a silky luster and the surface is somewhat rough. The color is a very dark brownish black. The brownish shade may be due to macerated spores. At the base of the upper shale this same kind of rock contains an abundance of brown and black spores of several types.

Among Kansas geologists the presence of these spores is generally regarded as

TABLE I

DATA ON WELLS USED IN STUDY OF KINDERHOOK DOLOMITE

Company, Well No. 1, Sec., Township South, Range		Upper Shale		Dolomite		Lower Shale		Viola Top	Simpson Top	"Wilcox" Top
		Top	Thickness	Top	Thickness	Top	Thickness			
Bell, Austin	28-23-1 E.			3,412	58	3,470	38	Absent	3,508	3,520
Marland, Vancil	8-24-2 E.	3,170	104	3,274	64	3,340	30?	3,370?	3,381	3,386
Liggett, Davis	7-24-1 E.	3,358	105	3,463	77	3,540	?			
Holbart, Gingrass	8-24-1 E.	3,367	88	3,455						
P. & A., Ady	16-24-1 E.	3,362	88	3,450?						
H. & Sk., Seaman	26-24-1 E.	3,385	80	3,465	31	3,496	?			
Lauck, Boller	29-24-1 E.	3,410?	95	3,505	50	3,555	6	3,561	3,578	3,588
B. & G., Moulds	7-24-1 W.	3,640	69	3,709	94	Absent		3,803		
Jolly, Showalter	11-24-1 W.									
A. & F., Hawks	16-24-1 W.	3,536	79	3,615	45	3,660	15			
Atlantic, Williams	30-24-2 W.	3,795?	42?	3,837	43	3,880	35	3,915	3,935	3,975
Shaffer, Elberson	15-24-3 W.	3,770?	67?	3,837	65	3,905	35	3,940	3,970	3,980
Sinclair, Boyle	17-24-3 W.	3,780	32	3,812	38	3,850	60	3,910		3,940
Meridian, Evans	6-25-2 E.			3,403	67	Absent		3,470		3,500
Aylward, Harrison	23-25-2 E.	3,125	70	3,195	30	3,225	10	3,235	3,250	3,255
Carlock, Whitson	25-25-2 E.	3,140?	45	3,205	35		0	3,240	3,265	3,270
Faulkner, Metcalf	6-25-1 E.	3,412	78	3,490	17	3,507	23	3,530		3,553
Continental, Black	9-25-1 E.	3,323?	71	3,394	18	3,412	30	3,442		3,465
P. & L., Mayall	11-25-1 E.	3,410?	74	3,484	36	3,520	17	3,537	3,548	3,560
Continental, Hampson	15-25-1 E.	3,335	76	3,411	25	3,436	15	3,451		
Skelly, Stearns	17-25-1 E.	3,260	72	3,332	21	3,353	25	3,378		
Steinb., Schaeffer	18-25-1 E.	3,412	75	3,487	53	3,540	25	3,565		3,600
Patton, Burnham	22-25-1 E.	3,324	71	3,395	22	3,417	21	3,438	3,444	3,451
Frost, Ramsey	31-25-1 E.	3,351?	82	3,433	17					
C. & S., Wyatt	3-25-1 W.									
Liggett, Valentine	4-25-1 W.									
BuViBar, Sefton	12-25-1 W.	3,403	49	3,452	55+	Two zones of dolomite				
Center, Austin	28-25-1 W.	3,660						3,770	3,793	3,800
Marshall, Dick	4-25-2 W.	3,835	25	3,860	25	3,885	40	3,925	3,940	3,950
Lion, Creaser	14-25-2 W.	3,815	45	3,860	15	3,875	12	3,887	3,905	3,930
Ryan, Williams	17-25-2 W.	3,835	35	3,870	30	3,900	10	3,910	3,925	3,938

good evidence that the containing rock is Mississippian (Kinderhook or Chattanooga) in age.[4]

The thickness of the upper shale is given in Table I. Apparently the maximum is 105 feet in the northeastern part of the area studied and as low as 25 feet in the southwestern part. The thickness in T. 25 S., R. 1 E., where the Kinderhook dolomite is typically developed, is approximately 75 feet. The character of the shale is uniform and generally of such nature that it would ordinarily be called Chattanooga. As a rule, the upper two thirds of the shale body consists of black shale which is smooth and rather dull in luster. The lower third is ordinarily silky in luster, very slightly micaceous, and speckled with numerous minute brown spots. In many wells the lowest 5 feet are abundantly supplied with spores (of three

[4] Wallace Lee, "Subsurface Mississippian Rocks of Kansas," *Kansas State Geol. Survey Bull. 33* (1940), Pl. 2.

different sizes). Such spores were noted in the wells in T. 24 S., R. 1 W., T. 25 S., R. 1 E., and T. 25 S., R. 1 W. In T. 25 S., R. 1 E., all the wells in Secs. 6, 9, 17, 18, 22, and 31 show abundant spores at the base of the black shale section. It is possible to differentiate three different genera ? of spores in these wells.

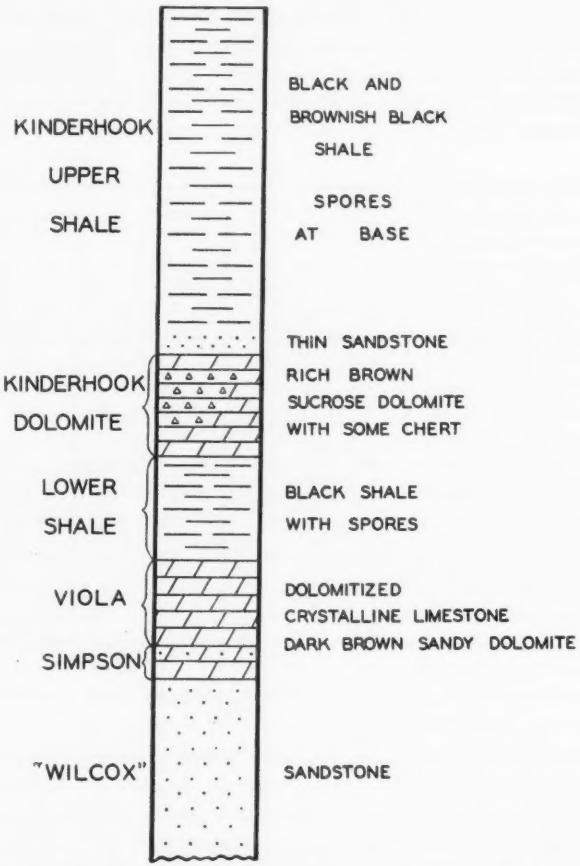


FIG. 1.—Generalized section to show stratigraphic position of Kinderhook dolomite in type area, T. 25 S., R. 1 E.

Locally the upper shale contains shales of different color and character. For instance, in Sec. 7, T. 24 S., R. 1 E., there are thin green shales at various levels. In the Boller well nearby there is gray micaceous shale at the base of the shale section. In the Williams well, in Sec. 30, T. 24 S., R. 2 W., there is some micaceous siltstone present. In the Whitson well (Sec. 25, T. 25 S., R. 2 E.) there

is some green shale present with the black. Frost's Ramsey well No. 1 shows black shales at the top, gray silty micaceous shales in the middle, and black shales at the base withnumerous spores.

BASAL SANDSTONE

In many of the wells studied there is a very thin zone of sandy material between the upper shale and the Kinderhook dolomite. The grains of sand are generally well rounded and commonly frosted. Some grains are poorly cemented so that the samples show loose grains only. In a few wells there is much dolomitic or calcareous cement. The best example of this condition is a well in Sec. 13, T. 24 S.,

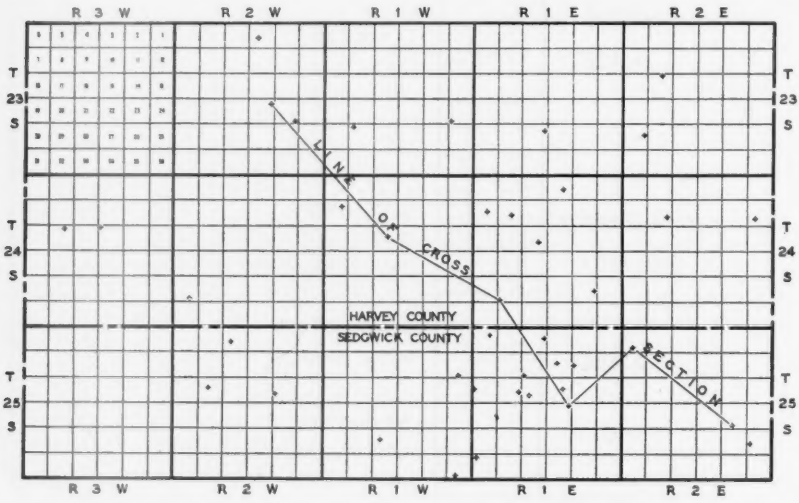


FIG. 2.—Map to show locations of wells studied and also line of cross section for wells shown in Figure 3.

R. 2 E., where the sand grains are scattered rather sparingly through a grainy, white, flaky limestone. In some wells only the top layer of the Kinderhook dolomite shows the presence of these wind-blown sand grains. There they are sparingly imbedded in the typical sucrose dolomite. All the wells in T. 24 S., R. 1 E., show the sandstone present, with the exception of the well in Section 8. Similarly, all wells listed in Table I, in T. 24 S., R. 2 W., and R. 3 W., show sandstone at the base of the black shale section. Two of the wells in T. 25 S., R. 2 E., have the sandstone, but the well in Section 23 does not. Of the wells listed in T. 25 S., R. 1 E., the following do not have sandstone: 6, 9, 15, 18, 32, and 31. The well in Section 9 has a very exceptionally dolomitic layer (with large round calcareous lumps), 14 feet above the base of the upper shale. No basal sandstone was found in the wells in T. 25 S., R. 1 W., or 25 S., R. 2 W.

NATURE OF KINDERHOOK DOLOMITE

The dolomite member of the Kinderhook sequence which lies under the upper shale has interesting lithology which is rather characteristic and can be traced from well to well. The color to the dolomite is commonly rich brown, although exceptionally it is nearly white and in some places may be pale cream. Even more striking is the texture of the dolomite. It is generally sucrose, revealing individual rhombs, rather small, but very nearly uniform in size. On account of a certain amount of porosity the rock therefore has a prominent sparkling appearance under the microscope. The porosity seems to be uniformly present in all parts of the member.

Considerable chert was deposited with the dolomite. Unfortunately, neither the percentage nor the character of the chert is uniform. In general, the percentage of the chert is greatest near the top of the Kinderhook dolomite member, and in most wells the percentage decreases rather gradually toward the base. As a general rule, the lowest layers of the Kinderhook dolomite member are free from chert. At some levels the chert may make up 100 per cent of the rock layers.

In Bell's Austin well No. 1, the upper half of the Kinderhook dolomite member has 50 per cent of white speckled chert, and the lower half of the member is free from chert. In Marland's Vancil well No. 1 the upper half of the Kinderhook dolomite member contains 50 per cent white chert, but the lower half contains a peculiar white, glistening chert. In this lower half the chert forms almost 100 per cent of the rock mass.

In Liggett's Davis well No. 1, the upper half of the Kinderhook dolomite member has no chert, but the lower part is 90 per cent dull white to semi-opaque chert. In Holbart's Gingrass well No. 1, the upper half contains 50 per cent white chert, and the lower half is all chert (white opaque). In Hartman and Skaer's Seaman well No. 1 the Kinderhook dolomite member contains about 50 per cent chert which is all tripoli. The Kinderhook dolomite in the Boller well shows several peculiarities. Chert constitutes 100 per cent of the layers at the top, but the percentage gradually decreases downward. Furthermore, there are three kinds of chert present. One is the white opaque type; another is tripoli which has small minute dolomite rhombs imbedded in it; and the third is a translucent type of chert. The lower part of the Kinderhook dolomite member in this well is very finely crystalline, but the upper part shows the typical sucrose texture.

The Kinderhook dolomite member in the Moulds well also shows a number of exceptional features. At the top there are several thin layers of very finely crystalline, chunky dolomite. The upper fourth of the member contains 50 per cent white and tripolitic chert, the middle part is all dolomite, and the lower half consists of 40 per cent gray chert. In this well, furthermore, the Kinderhook dolomite member rests dirctly on the Viola formation. In the Hawks well there are two layers of dolomite instead of one. They are separated by 9 feet of black shale. The lower of the two layers consists of 60 per cent chert (which is white and tripolitic) in its upper part but contains no chert in its lower apart. In the Atlantic's Williams well

No. 1 there are also two layers of dolomite separated by black shale. In this case the lower layer of the Kinderhook dolomite member consists of 40 per cent white chert. The lowest 10 feet of this layer has spiny blue chert with black impurities.

Two wells were examined in T. 24 S., R. 3 W. In one of these (the Elberson well) the upper third of the Kinderhook dolomite member is all chert consisting of tripoli studded with small dolomite rhombs. The lower two thirds of the member is all dolomite. In the Boyle well there are two layers of dolomite separated by a thin black shale layer. The upper one of these two layers consists of 50 per cent chert which is partly tripoli studded with rhombs, and partly white opaque chert. In the lower layer there is no chert.

The Kinderhook dolomite member in the Meridian well (Evans No. 1) shows some exceptional features . For example, the top 17 feet is entirely dolomite and some of this is finely crystalline and chunky. Lower, where chert is present, it is gray speckled chert. In Aylward's Harrison well No. 1 there is peculiar white speckled chert which is present throughout the member. In Carlock's Whitson well No. 1, there is a peculiar brown, calcareous, glistening chert at 3,206–3,210 feet and also some tripoli studded with rhombs. From 3,220 to 3,240 feet the chert constitutes 20 per cent of the layer and it is dirty white and speckled.

In T. 25 S., R. 1 E., eight wells are listed in Table I and shown in Figure 1. This is the township in which the Goodrich pool is located, and the one in which the Kinderhook dolomite was first found productive. Here also there is considerable variation in the amount and kinds of chert. Most of the wells have white opaque chert. The well in Section 11, however, shows brown chert at the top, but ashen, spotted chert lower down. The well in Section 22 also shows brown chert at the top, but white opaque chert and dolomite-studded tripoli deeper. The well in Section 31 shows only dolomite in the Kinderhook dolomite member.

Two wells were examined in T. 25 S., R. 1 W. One of these on the Sefton farm shows two layers of dolomite—an upper thin layer from 3,424 to 3,430 feet and a thicker one lower. The well ends in this lower layer which contains chert in the middle part of its thickness. The chert is white and opaque. The samples on the Center Oil Company's Austin well No. 1 are incomplete and do not reveal the nature of the Kinderhook dolomite member. Two other tests in this township were drilled deep enough to penetrate the Kinderhook dolomite member. Unfortunately, in neither case were samples saved for study. These wells are located in Sections 3 and 4. Consequently, information on the nature of the dolomite in this critical township is very fragmentary.

In T. 25 S., R. 2 W., three wells were examined. The Dick well in Section 4 shows white opaque and tripolitic chert. This is abundant at the top of the member, but decreases downward. The Creaser well in Section 14 shows 100 per cent dolomite in the Kinderhook dolomite member. The Ryan well has dolomite with approximately 20 per cent chert in the zone of the Kinderhook dolomite member. The chert is white.

Three wells were examined in T. 26 S., R. 1 W. All these wells showed that the Kinderhook dolomite is entirely absent. The well in Section 12 shows gray shale,

gritty and micaceous in the interval where the Kinderhook dolomite could be expected. This is Continental's Lambe well No. 1. Examination of samples from wells in Secs. 1, 3, and 31, T. 26 S., R. 2 W., shows that the Kinderhook dolomite member is absent in that township. In these wells either the upper shale or the sandstone rests directly on the dolomitized Viola formation.

LOWER SHALE

The thickness of the shale layers below the Kinderhook dolomite is given in Table I of wells used in this study. It may be noted that the thickness varies from zero in Sec. 7, T. 24 S., R. 1 W. (also Sec. 6, T. 25 S., R. 2 E., and Sec. 25, T. 25 S., R. 2 E.) to a median figure of approximately 25 feet in T. 25 S., R. 1 E. The maximum in the area surveyed is 60 feet in Sinclair's Boyle well No. 1. In nearly all wells this shale is black. Some of the wells show brownish black, slightly micaceous, shale exactly like the shale above the Kinderhook dolomite. This is the typical Chattanooga type shale. In Lauck's Boller well No. 1 there is much gray calcareous shale with a thin sliver of the typical brownish black shale at the base. The same may also be said about the shale in Sinclair's Boyle well No. 1 which has a thin brownish black layer at the top which is characterized by numerous spores, and has another black layer at 3875 to 3877 feet. The remainder of the shale in this well is gray, gritty, and micaceous with macerated fragments of spores.

In T. 25 S., R. 1 E., where the Kinderhook dolomite is typically developed, the shale below the dolomite is generally brownish black, finely micaceous shale, abundantly supplied with *Sporangites huronense*. The spores are not present in every well, but may be seen especially in wells in the following sections (see Table I): 6, 9, 15, and 22. All samples from these wells are cable-tool samples and very good. Therefore, there is little doubt about the spore-bearing shale being in place. The well in Section 6 has spores both in black shale and also in gray shale. Some of the shale in Continental's Black well No 1. is gray in color and contains large spores. An interesting variation is found in the Mayall well (Sec. 11) which has a shale abundantly supplied with small round phosphate pellets. The Hampson well (Sec. 15) has black waxy shale full of spores. The well in Sec. 28, T. 25 S., R. 1 W., contains brownish black shale with numerous spores. One well in T. 25 S., R. 2 W. (Sec. 4) shows some green shale and also considerable gray, silty shale. This is the only well in which the green color was seen. Incidentally, the samples in this well between the depth of 3905 to 3925 feet are unreliable.

Inasmuch as there is a major unconformity between the lower shale and the underlying rocks it is rather remarkable that the thickness does not vary more. This fact, coupled with the fact that the shale is almost everywhere typical black Chattanooga type, and especially the fact that it contains spores in so many places, seems to prove that it is part of the Kinderhook sequence.

UNDERLYING ROCK

The formation which underlies the Kinderhook shale, in nearly every well studied, is the Viola coarsely crystalline limestone. In the area under considera-

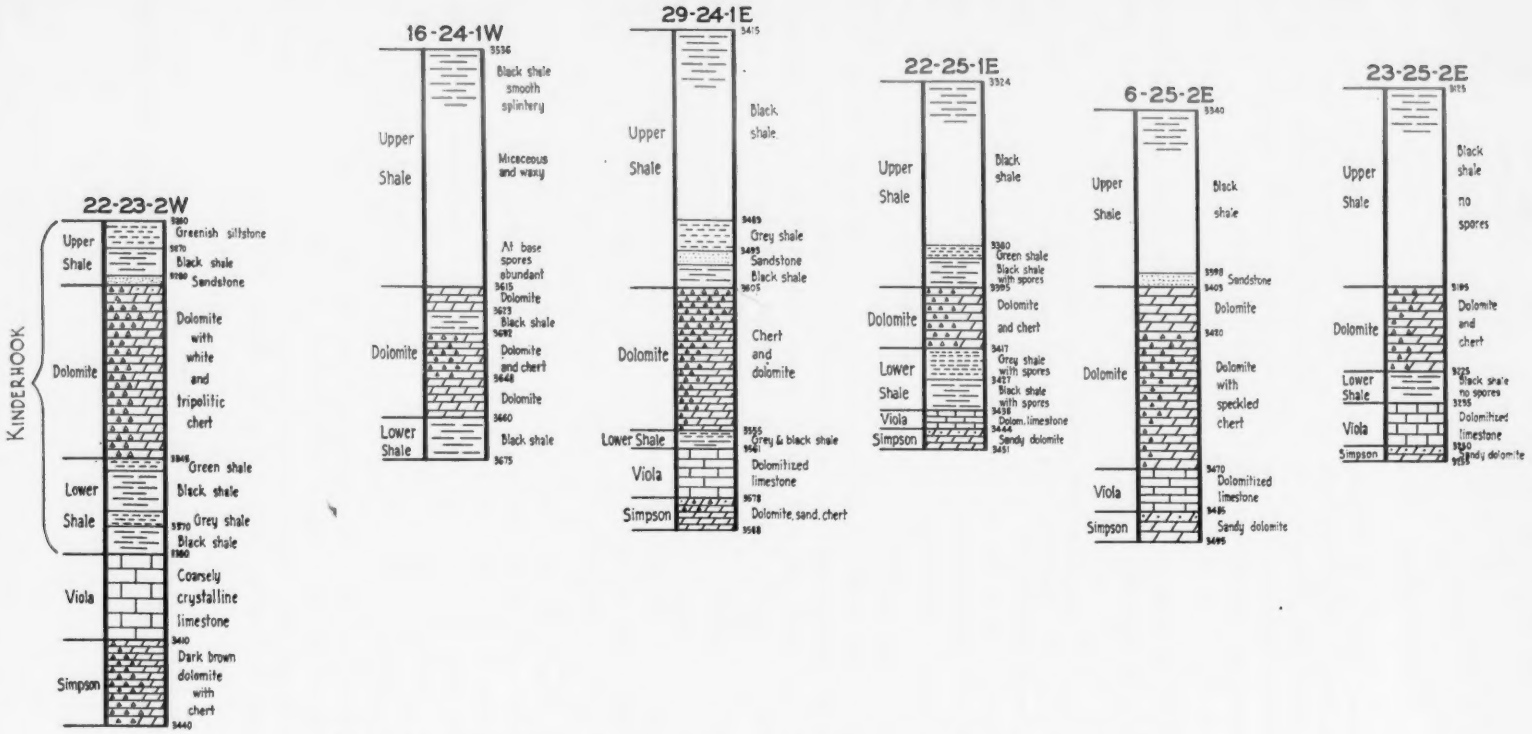


FIG. 3.—Cross section from northwest to southeast to show changes in stratigraphy of Kinderhook strata.

tion this limestone has been dolomitized almost completely without losing its textural characteristics. In acid it reacts like dolomite and small rhombs are cast off. Many wells show that the Viola was porous and that secondary rhombs of dolomite were formed in the vugs. The thickness of the Viola is not great, as shown in Table I. In fact, considering how thin it is, one wonders how it could be preserved intact over so large an area during the period of erosion between Ordovician and Mississippian time.

SIMPSON DOLOMITE

Immediately below the Viola a very peculiar and very thin dolomite is generally found. It is very dark in color, is dense, finely crystalline and chunky. Thus it stands in sharp contrast to the light colors of the Viola above it. Commonly this dolomite contains some chert which is also dark in color. Another uniform characteristic is that it is studded with wind-blown sand grains. These occur only at the very top of the thin dolomite layer. Here also is found a peculiar opaline quartzite in many wells. The full implication of these abnormal features is not known at present.

"WILCOX" SANDSTONE

Below the dolomite described in the preceding paragraph is, in every well, a thick body of sandstone which has well rounded and generally frosted grains. The grains are somewhat uneven in size and vary from medium to coarse in texture. There is a certain amount of secondary recrystallization present in the sandstone, as revealed by the sparkling crystal faces. Toward the base of the sandstone some wells show a very dark green shale (almost black in color) which contains some imbedded sand grains and some phosphate nodules. At greater depth, the color of the shale is pea-green, a color typically associated with the Simpson formation of central Kansas.

RECAPITULATION

In the area where the Kinderhook dolomite is well developed it is underlain by brownish black shale which contains abundant spores in a number of wells. For that reason the writer believes that the lower shale should be included in the Mississippian system. This determination would then mean that the dolomite above it must also be Kinderhook in age. In the past it has been called Hunton, Misener dolomite, and Viola. The name Viola is especially used where the dolomite rests directly on the coarsely crystalline white Viola characteristic of Kansas stratigraphy. This is the case in Sec. 6, T. 25 S., R. 2 E., and in Sec. 25, T. 25 S., R. 2 E., and perhaps other places in the area.

It will now be interesting to examine more wells between this area and the so-called Hunton outlier in Harvey County. The presumptive evidence indicates that the rock which has been called Hunton in that part of Kansas for many years may actually be the correlative of the Kinderhook dolomite.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 10 (OCTOBER, 1946), PP. 1756-1763, 1 FIG.

CORRELATION OF PALEOZOIC ROCKS ACROSS LAS ANIMAS ARCH IN BACA, LAS ANIMAS, AND OTERO COUNTIES, COLORADO[1]

JOHN C. MAHER[2]
Tulsa, Oklahoma

ABSTRACT

The Skelly Oil Company's Hankins well No. 1 in southeastern Baca County, Colorado, low on the southeast flank of the Las Animas arch, penetrated a sequence of Paleozoic rocks about 5,500 feet thick, before being abandoned at a depth of 6,171 feet in the Arbuckle limestone. The sequence is, in general, similar to that present in southwestern Kansas, and includes formations of Permian, Pennsylvanian, Mississippian, Ordovician and Cambrian age. Nearly three-fourths of the sequence is absent in the Marland Production Company's Mesa well No. 1 and the Phillips Petroleum Company's Haskins well No. 1 near the crest of the arch. There, beds of Permian age overlie a thin remnant of the Arbuckle limestone which, in turn, overlies rocks of pre-Cambrian age. Pennsylvanian rocks of considerable thickness are present on the west flank of the arch, as revealed by the Carter Oil Company's stratigraphic test No. 1 in southwestern Otero County. The Mississippian formations, and the Viola limestone and Simpson group of the Ordovician system are absent in the Carter well, however, and beds of Morrowan age overlie the Arbuckle limestone which, in turn, overlies rocks of pre-Cambrian age.

INTRODUCTION

The Las Animas arch is a major structural feature that extends northeastward across northeastern New Mexico and southeastern Colorado. A subsurface cross section, across the arch, is shown on Figure 1, and the line of the section is shown on the index map. The section includes the following wells: (1) Carter Oil Company's stratigraphic test No. 1, SE. cor., Sec. 30, T. 26 S., R. 57 W., Otero County; (2) Phillips Petroleum Company's Haskins No. 1, NW. ¼, NE. ¼, NE. ¼, Sec. 23, T. 29 S., R. 56 W., Las Animas County; (3) Marland Production Company's Mesa No. 1, NW. ¼, SE. ¼, NE. ¼, Sec. 8, T. 30 S., R. 50 W., Baca County; and (4) Skelly Oil Company's Hankins No. 1, SE. ¼, SE. ¼, NW. ¼, Sec. 34, T. 33 S., R. 44 W., Baca County, Colorado.[3] The information shown on the cross section represents a part of a regional investigation of the subsurface geology of southwestern Kansas and southeastern Colorado, being conducted by the Federal Geological Survey, in cooperation with the State Geological Survey of Kansas, and is released in this preliminary form because of the current interest in the area.

The writer is indebted to many geologists and oil companies for their aid and cooperation in the regional subsurface investigation. The well cuttings and electric logs discussed herein were generously loaned by the Skelly Oil Company, the Shell Oil Company, the Pure Oil Company, the Carter Oil Company, and the Colorado School of Mines. L. G. Henbest of the Federal Geological Survey iden-

[1] Manuscript received, September 4, 1946. Published by permission of the director of the Geological Survey, United States Department of the Interior.

[2] Geologist, Geological Survey.

[3] The well elevations used in the preparation of this section are those reported at the time each well was drilled. Some of these may be in error.

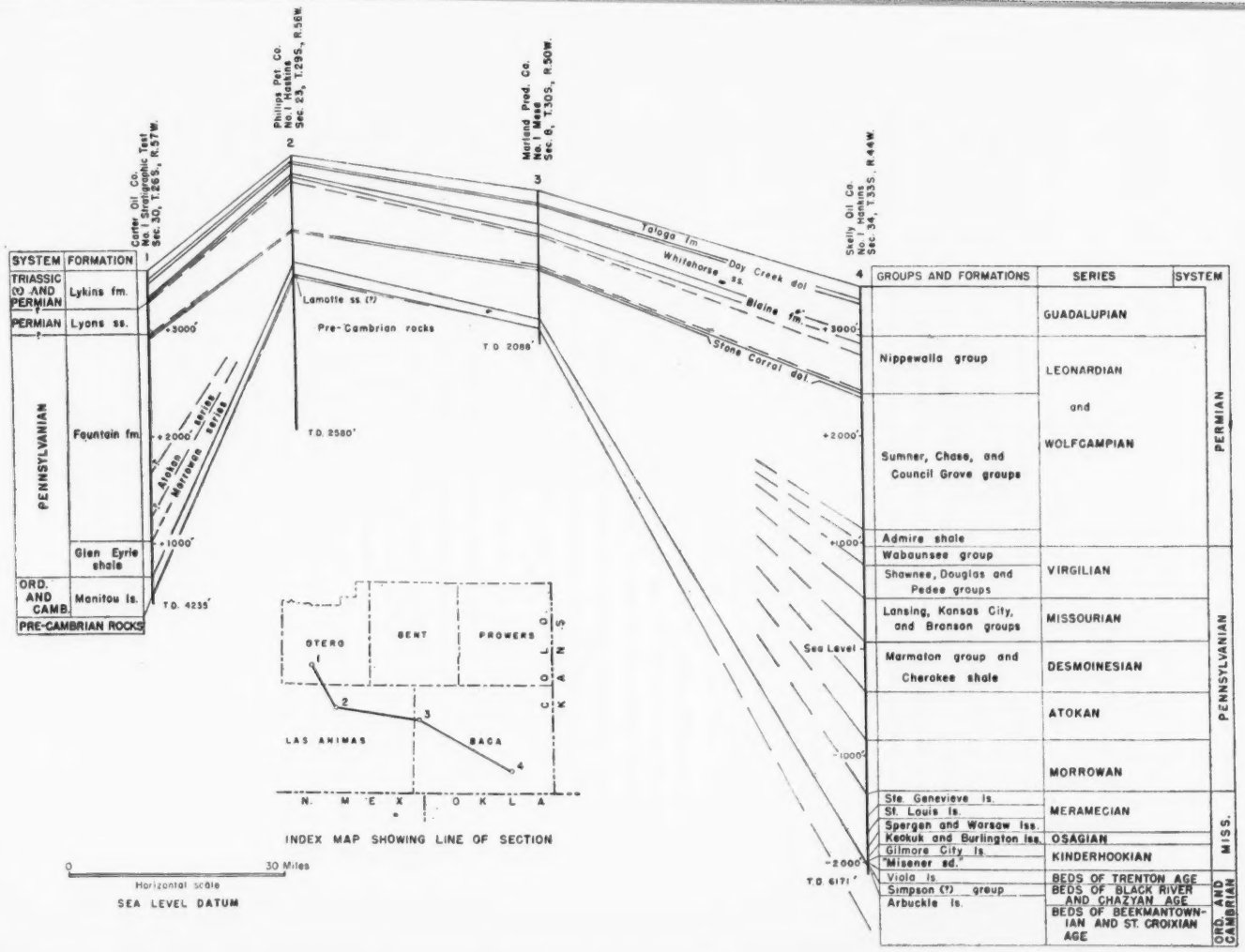


FIG. 1.—Correlation of Paleozoic rocks across Las Animas arch in Baca, Las Animas, and Otero counties, Colorado. Stratigraphic classification on right is mainly after State Geological Survey of Kansas; that on left follows common usage in Colorado.

tified the fusulinids from the well cuttings and aided greatly in establishing the Pennsylvanian correlations shown. The writer is indebted to H. D. Miser and N. W. Bass for their careful review of the manuscript.

PALEOZOIC ROCKS

Microscopic examination of well cuttings shows that along the line of the cross section rocks of early Permian, Pennsylvanian, Mississippian, and Middle Ordovician age wedge out against Lower Ordovician and Cambrian strata, which extend over the arch and overlie pre-Cambrian igneous and metamorphic rocks. The total thickness of the Paleozoic rocks is about 5,500 feet in well 4 on the east flank of the arch, about 1,100 and 1,300 feet in wells 3 and 2 on the arch, and about 3,000 feet in well 1 on the west flank. These Paleozoic rocks and their correlation with the Kansas geologic section are discussed briefly herein, beginning with the youngest. The terminology on the east end of the section follows that of the State Geological Survey of Kansas for the most part; that on the west end corresponds with common usage in Colorado.

PERMIAN SYSTEM

The Permian rocks of this area consist principally of red shale, sandstone, dolomite, anhydrite, and thin stringers of salt. A few beds of marine limestone and shale are present in the lower part of the system in well 4 and they appear to wedge out westward against the east flank of the arch. The thickness of the Permian rocks ranges from a maximum of 2,430 feet in well 4 to a minimum of 1,000 feet in well 2. Beds in the upper part of the system crop out at well 2.

GUADALUPIAN SERIES

The uppermost Permian rocks in the area traversed by the section belong to the Taloga formation of the upper part of the Guadalupian series. The formation consists of maroon shale, red silty sandstone, and thin beds of buff dolomite; its thickness in the four wells ranges from 60 to 120 feet. The Day Creek dolomite, underlying the Taloga formation, consists mainly of white and pink finely granular anhydrite. In well 3, however, the formation consists of cream-colored finely granular dolomite. Its thickness in the four wells ranges from 14 to 40 feet. The Whitehorse sandstone, the next underlying formation, consists of fine red silty sandstone, maroon sandy shale, and green-spotted maroon shale. It is possible that the beds designated herein as Whitehorse may include the Dog Creek shale of Kansas. The thickness of the formation ranges from 95 to 310 feet.

The upper part of this sequence of beds is exposed at the site of well 2. On the basis of lithologic similarity and stratigraphic position of these exposed beds and the Lykins formation of the northern Front Range, many geologists have tentatively designated the exposed beds as belonging to the Lykins formation. The Lykins formation is classed as being Triassic (?) and probably Permian in age. Nevertheless, the examination of well cuttings suggests that the Guadalupian

series, the underlying Blaine formation, and possibly a few feet of red shale beneath the Blaine probably are equivalent to the so-called Lykins formation in wells 2 and 1.

LEONARDIAN AND WOLFCAMPIAN SERIES

The Leonardian and Wolfcampian series include several groups and formations, only a few of which were identified in the well cuttings. In Kansas the Nippewalla group of the Leonardian series includes the Blaine formation, Flowerpot shale, Cedar Hills sandstone, Salt Plain formation, and Harper sandstone. The thickness of the group in the four wells on this section ranges from 405 to 532 feet. Only the Blaine formation, which is an excellent subsurface marker bed, was identified. It consists chiefly of white to pink granular anhydrite with thin beds of buff finely crystalline dolomite and maroon shale, and ranges from 20 to 120 feet in thickness. Beds of red silty sandstone, orange coarse-grained sandstone, red sandy shale, and a few thin beds of anhydrite, dolomite and salt, underlie the Blaine formation. The orange coarse-grained sandstones commonly are referred to by petroleum geologists as the "Cedar Hills sandstone." The entire sandy sequence, 300 to 500 feet in thickness, can be traced over the arch and appears to be correlative, at least in part, with the Lyons sandstone of the Front Range.

The Sumner group of the Leonardian series and the Chase and Council Grove groups of the Wolfcampian series, ranging in total thickness from 260 to 1,225 feet, underlie the Nippewalla group. Beds of Sumner and possibly Chase age extend over the arch but only the Stone Corral dolomite at the top of the Sumner group is constant enough to provide a reliable correlation. The Stone Corral dolomite is 20 to 40 feet thick and consists principally of buff finely crystalline dolomite and white granular anhydrite with some interbedded maroon shale. White to pink finely crystalline limestone is present in well 3. The remainder of the Sumner, Chase, and Council Grove groups consists mainly of red shale and fine-grained sandstone and thin beds of anhydrite, dolomite, and salt. In well 4, however, the lower part of the sequence is composed of buff to gray fossiliferous limestone and gray shale. This basal marine sequence, 148 feet thick, includes the Grenola and Foraker limestones of Kansas.

The Admire shale, 100 feet thick, underlies the undifferentiated Sumner, Chase, and Council Grove groups in well 4. There it consists of beds of maroon and gray shale, thin fossiliferous limestone, and brown micaceous sandstone. It is not present in wells 2 and 3.

PENNSYLVANIAN SYSTEM

Pennsylvanian rocks, more than 2,300 feet thick, are present in well 4 on the east flank of the arch. There beds of Virgilian, Missourian, Desmoinesian, Atokan, and Morrowan age have been tentatively identified. These beds are missing from the crest of the arch along the line of this section as shown by wells 2 and 3. In well 1 on the west flank of the arch, rocks of Atokan and Morrowan age have been tentatively identified but, due to lack of lithologic control and

fossil evidence, the rest of the Pennsylvanian rocks have not been subdivided. It seems possible to the writer that some of the upper maroon shale sequence in well 1, commonly placed in the upper part of the Fountain formation and therefore in the Pennsylvanian system according to the nomenclature used in Colorado, may be equivalent to some Permian beds in well 4.

VIRGILIAN SERIES

The Wabaunsee group, 180 feet thick in well 4, consists of beds of buff fossiliferous finely crystalline limestone, maroon and green shale, and some thin-bedded brown to gray micaceous sandstone. The unconformable contact of this group with the underlying Shawnee group is difficult to determine satisfactorily and has been tentatively placed at the base of a sequence of interbedded maroon and green shale, and fine-grained sandstone overlying gray fossiliferous finely crystalline limestone. The upper part of the Shawnee group consists predominantly of gray to white fine-grained sandy limestone containing some fusulinids identified by L. G. Henbest of the Geological Survey as immature *Triticites* sp. of probable Virgilian age. The middle part of the group consists chiefly of gray-white calcareous fine-grained sandstone, and dark maroon shale at its base. The lower part consists of gray sandy limestone, gray-black shaly limestone, buff to cream oölicastic limestone, and black shale. Beneath the Shawnee group in this well is a clastic sequence, 66 feet thick, which probably represents either or both the Douglas and Pedee groups. The sequence is characterized by feldspathic calcareous sandstone, fragmental limestone containing arkosic material, and variegated shale. The fusulinids *Ozawainella* sp. and *Triticites* sp. were identified by Henbest in the samples from these beds.

MISSOURIAN SERIES

The Lansing, Kansas City, and Bronson groups of the Missourian series commonly are treated as a single unit by oil geologists. This unit was identified in well 4 where it is about 380 feet thick. There it is principally buff, white, and gray sandy limestone with thin beds of limy sandstone, green shale, and maroon shale. Small oölites are common in the upper and lower limestones; feldspathic material is included in the limestones at the base. Henbest reported specimens of fusulinids from this sequence in well 4 include immature *Dunbarinella* or early *Triticites* sp. *Triticites* sp., *Ozawainella* sp., and *Triticites* of *T. irregularis* group.

DESMOINESIAN SERIES

The Marmaton group and the Cherokee shale which compose the Desmoinesian series have not been differentiated in well 4. The base of the series is rather indefinite so an arbitrary base has been drawn at the bottom of an arkosic sandstone that marks a change from dark-colored limestones and shales above to light-colored glauconitic and fossiliferous limestones and green shales below. The fusulinids *Fusulina* sp. and *Wedekindellina* sp. indicative of Desmoinesian age were identified by Henbest in the limestone beds lying between 200 and 300 feet above this arkosic sandstone; specimens of the fusulinid *Fusulinella* were found

several hundred feet below it. The beds thus assigned to the Desmoinesian series in well 4 are about 470 feet thick and consist principally of maroon waxy to black calcareous shale, gray-buff to black oölitic and crinoidal limestone, and gray calcareous sandstone.

ATOKAN SERIES

Beds of cream-colored glauconitic limestone containing bryozoans and brachiopods, black dense limestone, green and black shale, and arkosic sandstone are present in well 4 beneath the Desmoinesian rocks as delimited above. A coarse white subangular sandstone, tightly cemented with calcium carbonate, is present at the base of this sequence. The Atokan series is about 625 feet thick and contains specimens of the fusulinid *Fusulinella*. In well 1 on the west side of the arch, the series is only 413 feet thick and consists predominantly of arkose. The writer tentatively considers this sequence as equivalent to the Atoka formation of Oklahoma and follows the recent suggestion of Spivey and Roberts[4] in elevating the name Atoka to series rank.

MORROWAN SERIES

The lower 520 feet of the Pennsylvanian system in well 4 consists mainly of green fossiliferous shale, black calcareous shale, cream to buff glauconitic and fossiliferous limestone, and a basal quartzitic sandstone and arkosic conglomerate. The beds of limestone and shale contain many bryozoans and crinoids. This sequence is tentatively classified as the Morrowan series in Figure 1 because the lithologic character of the beds resembles that of rocks known to contain Morrowan fossils in near-by wells. Approximately the same sequence of beds present in well 4 is present in well 1, except that the beds in the upper 292 feet are arkosic. The sequence is 558 feet thick in well 1. The fusulinid *Millerella* sp. was identified by Henbest in one of the thin limestones in the arkosic upper beds and in several of the lower limestones in well 1. The lithology of the lower limestone and shale beds in both wells 1 and 4 corresponds with that of the Glen Eyrie shale of the Front Range. Recently Henbest[5] reported the fusulinid *Millerella* sp. in the Glen Eyrie shale and correlated it with the Morrow formation of Oklahoma and Arkansas.

MISSISSIPPIAN SYSTEM

Mississippian rocks are present only in well 4 on the east flank of the Las Animas arch. There they are 630 feet thick and may be readily subdivided and correlated with the Mississippian formations present in western Kansas.

MERAMECIAN SERIES

Ste. Genevieve limestone.—The Ste. Genevieve limestone, whose thickness is

[4] R. C. Spivey and T. G. Roberts, "Lower Pennsylvanian Terminology in Central Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 30, No. 2 (February, 1946), pp. 185–86.

[5] L. G. Henbest, "Stratigraphy of the Pennsylvanian, in the West Half of Colorado and in Adjacent Parts of New Mexico and Utah" (abstract), Program, 31st Annual Meeting, *Amer. Assoc. Petrol. Geol.* (April, 1946), p. 23.

200 feet in well 4, consists chiefly of cream-colored finely sandy and oölitic limestone containing some fragments of reworked orange-stained chert. A bed of buff cherty limestone, about 30 feet thick, is present near the middle of the formation.

St. Louis limestone.—The St. Louis limestone, which is 140 feet thick in well 4, is composed mainly of thick beds of buff oölitic to brown dense limestone, and thin beds of cream-colored finely granular dolomite and dolomitic limestone. Small amounts of brown to tan dense chert are present in some of the limestones.

Spergen and Warsaw limestones.—The Spergen and Warsaw limestones, undifferentiated, are 145 feet thick in well 4; they consist for the most part of beds of gray-buff resinous-appearing dolomite and dolomitic limestone containing gray-white opaque chert, and gray silty dolomitic limestone containing white quartzose chert. Thin khaki-colored shales separate the limestones near the base.

OSAGIAN SERIES

Keokuk and Burlington limestones.—The Keokuk and Burlington limestones, whose thickness is 95 feet in well 4, are characterized by cream-colored to gray finely granular dolomite containing much white figured or fossiliferous chert and minor amounts of glauconite and quartz. A buff-brown oölitic limestone is present in the upper half of the unit.

KINDERHOOKIAN SERIES

Gilmore City limestone.—The Gilmore City limestone in well 4 is composed of an upper bed of white finely sandy and finely oölitic limestone about 15 feet thick, and a lower bed of cream-colored to buff, oölitic to pisolitic, crinoidal limestone, about 39 feet thick.

"*Misener sand.*"—A bed of fine-grained sandstone and green sandy pyritic shale, about 6 feet thick, underlies the Gilmore City limestone in well 4. This bed resembles rocks of Simpson age and has been so classified by some geologists. The writer, however, considers this to be the basal Mississippian sandstone and refers to it as the "*Misener sand*," following the common usage of oil geologists in Kansas.

ORDOVICIAN AND CAMBRIAN SYSTEMS

In the opinion of the writer, all of the wells on this cross section penetrated rocks of Ordovician or Cambrian age. Wells 1, 2, and 3 penetrated 180 feet, 105 feet, and 80 feet, respectively of Arbuckle limestone before reaching pre-Cambrian rocks. Well 4 penetrated 117 feet of Viola, Simpson (?), and Arbuckle rocks, stopping 81 feet in the Arbuckle limestone.

BEDS OF TRENTON AGE

Viola limestone.—A cream-colored, partly green-stained, finely crystalline limestone, about 10 feet thick, marks the top of the Viola limestone in well 4. It contains an abundance of white dense chert and a small amount of greenish white dense pyritic chert. Some green sandy pyritic shale appears in the samples below this limestone; however, it is conceivable that this material may be cavings from

the "Misener sand." A gray-buff finely granular dolomite, about 12 feet thick, containing small pyrite inclusions and a large amount of white dense fossiliferous chert forms the base of the Viola limestone in this well. This lower bed, more than the upper limestone, resembles the typical cherty Viola limestone of Kansas. The entire sequence can be separated on the electric log as well as in the samples and is tentatively considered to be Viola in age.

BEDS OF BLACK RIVER AND CHAZYAN AGE

Simpson (?) group.—A white green-stained fine-grained sandstone interbedded with green sandy pyritic shale is present in the samples below the Viola limestone in well 4. The electric log of this well, when the off-scale part of the curves is replotted on one scale, indicates a small "break" at this position. This sand and shale sequence appears to be less than 10 feet thick and is very questionably referred to the Simpson group.

BEDS OF BEEKMANTOWNIAN AND ST. CROIXIAN AGE

Arbuckle limestone.—The Arbuckle limestone extends across the Las Animas arch along the line of this section. It is overlain by Pennsylvanian rocks in well 1 on the west flank, by Permian rocks in wells 2 and 3 on the arch, and by younger Ordovician rocks in well 4 on the east flank. The Arbuckle limestone in these wells is chiefly cream-colored to buff finely crystalline to coarsely crystalline dolomite containing white to tan dense chert. The lower beds in wells 1 and 3 are red-stained, sandy, and glauconitic.

The presence of the Arbuckle limestone across the Las Animas arch in this area is noteworthy. The possibility that it may be present in other wells situated south of those herein shown is indicated by the drillers' log of a well drilled many years ago by the Mustang Oil Company in the NE. cor., SW. $\frac{1}{4}$, Sec. 36, T. 30 S., R. 52 W., near well 3. This log reports "pink lime turning to gray lime" between depths of 1,950 and 2,000 feet. No samples are available from this well. Another well, the Parker Club's Adams No. 1 in Sec. 32, T. 34 S., R. 56 W., penetrated a bed of dolomite between depths of 3,642 and 3,711 feet. Partial samples from this well do not prove conclusively that the dolomite is Arbuckle limestone but it is certainly older than Pennsylvanian.

Lamotte sandstone (?).—The basal Paleozoic sandstone is 15 feet thick in well 2. The samples of lower Arbuckle rocks from wells 1 and 3 contain some sand grains that resemble those of the Lamotte sandstone of Kansas, but one can not be certain that these grains are not derived from sandy dolomite in the lower beds of the Arbuckle. If the sandstone is present in these wells, it is less than 3 feet thick.

PRE-CAMBRIAN ROCKS

Pre-Cambrian igneous and metamorphic rocks were penetrated to depths of 70 feet in well 1, 1,470 feet in well 2, and 153 feet in well 3. The pre-Cambrian rocks in well 2 are predominantly metamorphosed sediments, some of which appear to be only slightly altered from their original state.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 10 (OCTOBER, 1946), PP. 1764-1771, 2 FIGS.

GEOLOGICAL NOTES

ALUNITE AT WOODBINE-EAGLE FORD CONTACT IN NORTHEASTERN TEXAS[1]

LLOYD W. STEPHENSON[2]
Washington, D. C.

The mineral *alunite*, a hydrous potassium aluminum sulphate, is present in the form of white nodules at the contact between the Woodbine formation and the overlying Eagle Ford formation at many localities in northeastern Texas, and has been observed at several other localities at lower stratigraphic positions within the upper part of the Woodbine formation. This announcement is of particular interest because of the few recorded occurrences of this mineral in sedimentary rocks. An earlier account of alunite in the Coastal Plain of Texas is given by Wherry,[3] who identified a sample from "Gonzales County" as referable to this mineral. Presumably the sample was obtained from Tertiary sediments, probably Eocene, which form the principal surface materials throughout that county.

When the white nodules in the Woodbine formation were first observed in 1929 they were thought to be kaolinic clay pebbles constituting a basal conglomerate of the Eagle Ford formation. Subsequent investigations showed the presence of nodules of this kind here and there along the line of outcrop of the Woodbine-Eagle Ford contact from northwestern Fannin County to southeastern Johnson County, a distance of about 135 miles. A few samples were collected at several localities.

In the summer of 1945 the Geological Survey initiated a project to prepare a detailed reconnaissance geological map of the Woodbine area in Texas, and Watson H. Monroe and Harlan R. Bergquist were assigned to carry on the necessary field surveys. In this connection, Monroe suggested that a more critical study be made of the white nodules, and a sample was submitted to C. S. Ross. A qualitative test showed that the mineral composing the nodules belonged in the alunite group. Additional representative samples were subsequently collected by Monroe and Bergquist along the line of outcrop of the Woodbine-Eagle Ford contact and were submitted to Ross for further confirmative studies, and his preliminary report is here quoted.

The alunite from the Texas localities merits detailed mineralogic study and such a paper together with complete chemical analyses will be published later. However, samples from representative localities from near the contact of the Woodbine and Eagle Ford, and one sample from a lower stratigraphic position within the Woodbine formation in

[1] Manuscript received, August 10, 1946. Published by permission of the director of the United States Geological Survey.

[2] Principal geologist, United States Geological Survey.

[3] Edgar T. Wherry, "Notes on Alunite, Psilomelanite, and Titanite," *U. S. Nat. Mus. Proc.*, Vol. 51 (1916), pp. 81–88.

Grayson County, have been examined by means of x-rays, and qualitative chemical tests, and these agree in showing that the nodules are characterized by a mineral of the alunite group. Microscopic examination shows that the material from all localities is essentially similar. The alunite occurs as a very fine grained crystal aggregate and no crystal boundaries are observable. Only the mean index of refraction ($n = 1.577 \pm .002$) is observable. The material resembles kaolinite but it is harder and has a harsher feel.

At most localities the alunite nodules are in fine, massive sand a few inches, or at most 15 inches thick, below a ledge of hard platy, calcareous sandstone or sandy limestone which forms the base of the Eagle Ford formation. However, the beds immediately associated with the alunite are not everywhere the same. The alunite may be in shale (Woodbine) instead of sand, and the calcareous sandstone which typically overlies the contact may be wanting, in which case the shale of the Eagle Ford rests directly on the alunite-bearing shale of the Woodbine. At some exposures of the contact the alunite nodules are wanting. Where present they constitute one of the useful criteria for determining the position of the contact. Representative localities at which alunite nodules have been seen are described in the following paragraphs. The places are treated in the order of their geographic occurrence from Fannin County in the northeast to Johnson County in the southwest.

Fannin County.—The most northeasterly locality at which alunite nodules have been recorded at the Woodbine-Eagle Ford contact is in a small headwater branch of Brushy Creek, just east of a culvert on an unimproved crooked road, 2.2 miles (airline) N. 37° E. of the center of Savoy, 2 miles east of the Grayson County line, in Fannin County. Here the alunite occurs in fine-grained tan sand below a ledge of hard calcareous, irregularly platy sandstone or sandy limestone 2 to 8 inches thick. The relationships are essentially the same as those in the cut on U. S. Highway 82 east of Whitesboro, Grayson County, except that several stringers of the white nodules are present in the sand instead of one, the lowest stringer being about 15 inches below the hard ledge. Samples were collected here by Bergquist and Stephenson. In a ditch of the same road about 200 feet farther east, 100 feet east of a driveway to a farmhouse, a line of alunite nodules in soft tan sand is present about 6 inches below the ledge of Eagle Ford sandstone.

Monroe and Bergquist have furnished a sample of alunite from the Woodbine formation in Fannin County at a stratigraphic position estimated to be 50 to 60 feet below the base of the Eagle Ford formation. The locality is on the west side of a north-south road 0.1 to 0.2 mile north of a cemetery, 5.5 miles (airline) N. 35° E. of the center of Savoy, 0.65 to 0.75 mile south of a graveled road. The following is their description of the section containing the alunite.

	Feet
Woodbine formation	
Sandstone, fine- to medium-grained, glauconitic, reddish brown; prints of oysters and other mollusks in upper 3 feet. Grades into soil. Top of sandstone at elevation 618 feet (barometer) and about 5 feet below top of hill	6
Sand, fine-grained, glauconitic, laminated by frequent partings of shale; streaked gray and mottled tan. (Dips north 5 to 6 feet in 100 feet)	3.3

Sandstone, fine-grained, glauconitic; laminated throughout by tan weathered tuffaceous material 1.5
Shale, silty to sandy, buff and gray with tan and yellow streaks in lowermost part, base gradational into alunite-bearing sand below; upwards the shale is prevailingly smooth and gray 6
Sand, soft, fine, tan, argillaceous with shale partings. About midway there is a 2-inch to 3-inch zone of gray clay pebbles or concretions that are rounded or flattened and even elongate-cylindrical and have the outer surface of dark brown to black color; associated with these are plant prints, and one turtle bone was collected. The pebble zone occupies an irregular position that ranges from a few inches to nearly 1½ feet above the base. The associated sand is slightly tuffaceous locally or may have limonitic stains. At the top of the bed is a zone of *alunite* present as streaks and flattened nodular masses or thin isolated nodules through an interval of 2 inches to 3 inches, in soft argillaceous tan sand. The nodules do not appear to exceed ½ inch in thickness but may be elongated as much as 3 to 4 inches 2
Fine sandstone, partly glauconitic, argillaceous, tan and brown; some cross-bedding; minor limonitic stains and streaks 6

Grayson County.—Near the eastern edge of Grayson County a locality similar in its relationships to the one 2.2 miles northeast of Savoy, Fannin County, is reported by Bergquist in a ditch east of a culvert on the north side of an unimproved road, 0.1 mile to 0.15 mile west of the Grayson-Fannin County line, 2.8 miles (airline) N. 19° W. of the center of Savoy. In a note accompanying the collection he says:

The nodules are in a fine-grained tan argillaceous sand, 3 inches to 6 inches below a thin bed of calcareous sandstone. The alunite appears to be a thin-layered deposit with a thickness that ranges from a mere ribbon streak to nodules 1½ inches long. In places there are white streaks disseminated in the sand around nodules. Scattered white spots occur in the calcareous sandstone. One-tenth mile to the east on the same road, in a bank opposite a frame house, near the county line, the material is present only as nodules and gives no indication of a continuous layer. At this point they average 9 inches below the calcareous sandstone. Samples were collected.

A shallow cut on U. S. Highway 82 near the crest of a west-facing slope of a headwater branch of Mustang Creek, 0.3 mile east of junction with road to Sadler, 4 miles east by south of Whitesboro, Grayson County, Texas (Fig. 1), exposes the following section.

Feet

Upper Cretaceous
Eagle Ford shale
Yellowish weathered shale with numerous small, thin flakes and laminae of limestone, poorly exposed 8
Irregularly thin-bedded, platy, hard calcareous sandstone, ripple-marked in places, and showing filled borings on under side of some platy layers; contains a few imprints of poorly preserved oysters, and a few prismatic fragments of shells of *Inoceramus* ..... ½–⅔
Soft, rather fine sand, with a few small pebbles 1½–1⅔
Disconformity, contact sharp and broadly undulating
Woodbine formation
Soft fine light-colored somewhat argillaceous sand, spotted and mottled with sulphur yellow; medium hard small sulphur-yellow nodules weather out of the sand. At the top of the sand immediately below the contact is a conspicuous line of white nodules of *alunite* of all sizes up to a maximum of 30 mm. in length (see photo); the nodules are of irregular form and roughened surface; as seen on a broken surface the material is pure white, of chalky uniform texture, and clings strongly to the tongue ..... At least 8

Although this section is not the discovery locality of alunite in northeastern Texas, it is a typical occurrence and is the most accessible one of the half-dozen or more known localities in Grayson County.

On the old Sherman road, 3 miles (airline) east by south of the center of Whitesboro, a shallow cut at the crest of a west-facing slope of a headwater branch of Mustang Creek reveals the basal calcareous platy sandstone of the Eagle Ford, underlain by the fine tan sand forming the uppermost part of the Woodbine formation. A stringer of alunite nodules is well developed a few inches below the platy sandstone. Samples were collected by Bergquist and Stephenson.

In a cut at bend in secondary road near crest of west-facing slope of Mustang Creek valley, 0.2 mile east of the crossing of the creek, and 1.3 miles east of the

FIG. 1.—Alunite nodules at contact of Woodbine and Eagle Ford formations in cut on U. S. Highway 82, 4 miles east by south of Whitesboro, Grayson County, Texas. Alunite is present as stringer of white nodules in fine sand at top of Woodbine, a few inches below hard, platy, calcareous sandstone of Eagle Ford.

center of Sadler, the alunite is present as thin streaks and scattered soft nodules closely below the hard calcareous basal ledge-making sandstone of the Eagle Ford. This is the discovery locality of the alunite nodules (1929). Samples collected by Bergquist and Stephenson.

On the same road about 1.5 miles east of Sadler, 0.1 mile west of a cemetery, several stringers of alunite nodules in the fine sand are well exposed within a foot below the ledge of hard calcareous sandstone.

Some of the exposures east of Whitesboro and east of Sadler show that the fine sand of the Woodbine, in which the alunite occurs just beneath the basal calcareous sandstone ledge of the Eagle Ford, is 15 or 20 feet thick, and is underlain by 40 feet or more of dark shale bearing fossiliferous septarian concretions. Some of the earlier workers have mistaken this dark shale for basal Eagle Ford.

Cut in north-south unimproved road, 0.2 mile south of road-T to west, 0.4 mile west of County highway, 4.95 miles (airline) N. 28° E. of center of Collins-

ville, 3.1 miles (airline) S. 49° E. of center of Whitesboro. Nodules in weathered shale under residual soil; some nodules as much as 2 inches in length. The geographic and topographic positions suggest that the alunite nodules mark the Woodbine-Eagle Ford contact. This locality was discovered by Bergquist, who collected a sample.

North side of unimproved road north of a house, 0.25 mile west of County highway, 4.15 miles (airline) N. 43° E. of center of Collinsville, 4.45 miles (airline)

FIG. 2.—Band of white alunite nodules at Woodbine-Eagle Ford contact in small branch of Little Elm Creek, about 0.2 mile east of north-south road, 3.65 miles north by east of Navo, 1.25 miles west by north of Smiley triangulation station, Denton County, Texas. Alunite band is in dark shale of Woodbine formation, immediately overlain by typical calcareous shale of Eagle Ford formation. Locality about 20 miles south of one shown in Figure 1.

S. 39° E. of center of Whitesboro. A few alunite nodules occur below platy, calcareous sandstone forming the base of the Eagle Ford. Bergquist discovered the alunite here and collected a small sample.

Cut of east-west unimproved road over a small hill, about 0.1 mile east of road-T to north, 3.4 miles (airline) N. 61° E. of Tioga, and 0.9 mile south of Range Creek. The hill is capped by platy calcareous sandstone forming the basal bed of the Eagle Ford, and alunite nodules are present below the sandstone. Discovered by Bergquist, who collected a sample. He also reports alunite nodules and sandstone flags on a hillside in a field, 0.3 to 0.4 mile north of the preceding. Still farther north he found alunite nodules in weathered sandy clay in a field beside the road, 0.15 mile north of Range Creek.

At one locality in Grayson County, Bergquist found and collected alunite at

a lower stratigraphic position in the Woodbine formation. On an unimproved north-south road, 0.5 mile north of Sandy Creek, 1.4 miles southwest of Independence School, 3.5 miles south of the center of Gordonville, typical white alunite nodules weather out of poorly exposed weathered, brownish clay at the side of the road. The nodule-bearing clay is overlain by 26 feet of poorly exposed weathered gray plastic clay with interbedded sandy layers of Woodbine aspect. The stratigraphic position is estimated to be at least 100 feet below the base of the Eagle Ford formation.

Denton County.—According to Monroe, the northernmost outcrop of alunite observed in Denton County is on the east-facing slope of a headwater branch of Mustang Creek, 4.9 miles east-southeast of Pilot Point, 6.9 miles northeast of Aubrey, and 3.0 miles north by east of Mustang, in the ditch on the south side of a private road about 100 feet east of a county road, and about 12 feet below the intersection. The alunite is in the top of shale of the Woodbine and is overlain by 4 feet of shale and calcareous sandstone flags, overlain in turn by black clay, both of the Eagle Ford formation.

The best known outcrop of the alunite seen in Denton County is on a small branch of Little Elm Creek (Fig. 2), about 0.2 mile east of a north-south road, 3.65 miles north by east of Navo, 1.25 miles west by north of Smiley triangulation station. (See State Highway Department road map.) The following description of the section is adapted from notes furnished by Monroe.

	Feet
Upper Cretaceous	
Eagle Ford formation	
Tan chalky shale	6.0
Bentonite	0.2
Tan chalky shale	1.0
Greenish brown sandy clay, glauconitic?	0.1
Tan chalky shale containing discontinuous slabs of platy sandstone	1.7
Disconformity, contact sharp	
Woodbine formation	
Brown shaly clay containing zone of alunite concretions (Fig. 2); sample collected	0.5
Dark gray to black hackley shale with yellow partings	4.0
	13.5

The basal ledge-forming calcareous sandstone of the Eagle Ford is wanting, and the alunite is developed in shale instead of sand.

In the ditch of an east-west road about 0.75 mile east of Lloyd, 3.5 miles northwest of Little Elm, Denton County, a few nodules of alunite were found weathered out of shale at a level which, from other evidence, had been determined as the approximate position of the Woodbine-Eagle Ford contact.

Monroe found alunite in a ditch on the west side of a county road about 2 feet below the lowest recognizable Eagle Ford shale about 2.5 miles west of the village of Little Elm and 3.7 miles north by east of the spillway in the Lake Dallas dam (Garza Dam).

In a borrow pit at the north end of Garza Dam a calcereous sandstone bearing reef-like accumulations of the shells of *Ostrea soleniscus* Meek is overlain by dark

selenite-bearing shale of the Woodbine type. Near the top of the slope white alunite nodules weather out of a poorly exposed layer of medium-grained sand, and in close association with the nodules are numerous fragments of hard, platy, calcareous sandstone such as are commonly present at the base of the Eagle Ford shale. The alunite nodules and the sandstone fragments are interpreted to mark the Woodbine-Eagle Ford contact. Just west of the north end of the dam in a low cliff along the shore of the lake the contact is marked by a few alunite nodules in a thin layer of sand at the top of the Woodbine.

Tarrant County.—In a borrow pit south of the Chicago, Rock Island, and Gulf Railway about 1.35 miles east by north of Tarrant Station, 0.15 mile east of Dorothy Siding, 0.9 mile west of the Dallas County line, there is exposed the full thickness of the unit which W. L. Moreman called the Tarrant formation of the Eagle Ford group, but which is here interpreted to be the uppermost part of the Woodbine formation. (See Adkins, *Univ. of Texas Pub. 3232* (1933), pp. 424, 425.) As exposed in this pit this unit consists of about 18 feet of shale resting on *Ostrea soleniscus*-bearing sandstone, and overlain by poorly exposed bed of thin, platy, sandy limestone, a few inches thick, typical of the basal Eagle Ford. Weathering out from beneath the limestone are white alunite nodules, which mark the Woodbine-Eagle Ford contact. Monroe collected a few of the nodules at this place.

Johnson County.—The locality farthest south at which alunite nodules have been found at the Woodbine-Eagle Ford contact is in a shallow cut of the Cleburne road adjacent to a cemetery, 1.2 miles northwest of the center of Grandview, Johnson County. At the crest of the cut is a 2-foot ledge of hard, irregularly bedded, platy, sandy limestone with interbedded thin clay layers and indications of weathered bentonite; some fragmentary oyster shells were observed, and the rock includes some small conglomeratic lenses containing shark teeth, fragmentary fish remains, shell fragments, and small sandstone pebbles. Beneath the hard ledge is a poorly exposed layer of soft argillaceous sand, one foot thick, in which are stringers of white nodules of alunite. This sand layer is underlain in the cut by 8 feet of gray sands and sandstones characteristic of the Woodbine formation, and similar rocks appear in the road ditch downslope toward the northwest, making a total exposed thickness of about 25 feet. Samples of alunite were collected at this locality by Monroe and Stephenson.

PREPARATION OF LANTERN SLIDES[1]

G. ZULOAGA[2]
Caracas, Venezuela

The lantern slides presented in connection with F. A. Sutton's paper "Geology of Maracaibo Basin, Venezuela,"[3] were the subject of much favorable comment by all who saw them at the Chicago meeting of the Association.[4] The negative slides, some prepared in colors, were particularly striking. At the suggestion of R. W. Clark,[5] the details of their preparation are here described.

These slides were prepared according to the instructions contained in the paper "Preparation of Lantern-Slide Copy," by Carl A. Moore,[6] to insure the proper proportions of letters, width of lines, and other pertinent details. The simple treatment given the slides to insure smooth texture and adherence of the colors was developed by the drafting section of the geological department of the Creole Petroleum Corporation. Moore has pointed out the limitations of negative slides, such as their tendency to heat and absorb light but they have many desirable features which should make them popular for more general use.

Perhaps the greatest single advantage of negative slides is their ease of preparation and the use of colors. Drainage, land boundaries, oil fields, pipe lines, geological features, and cultural details may all be shown on a single slide by the use of contrasting colors. The original map or chart is drawn on white paper in black ink. Care is taken to make certain that all lines to be colored are thick enough to yield clear lines on the negative.

The negative is washed carefully, on the emulsion side, with benzine to remove all grease and extraneous matter, and allowed to dry. The surface is lightly dusted with pumice, by using a bit of cotton, and then cleaned with the same material. The colors may then be applied and will adhere to the film readily, yielding a clean sharp picture. The same treatment may be given positive slides which are generally more satisfactory for geologic profiles, columnar sections, and maps of large areas.

The colors recommended for use on slides of this kind are, in order of intensity, the following: Dark Orange, Chrome Yellow, Apple Green, Turquoise Blue, Light Red, and Corn Color. All of these colors show well on the screen when used on negative slides where it is desirable to avoid dark colors which lack contrast against the black background. Dunne's transparent water colors were used on these slides but other brands should be equally satisfactory.

[1] Manuscript received, August 15, 1946.

[2] Creole Petroleum Corporation, manager of exploration.

[3] This *Bulletin*, pp. 1621–1741.

[4] 31st annual meeting, April, 1946.

[5] Chairman of technical program, for 32d annual meeting, Los Angeles, March, 1947.

[6] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 10 (October, 1942), pp. 1656–57. Reprints available, *gratis*, by writing Association Headquarters, Box 979, Tulsa 1, Oklahoma.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 10 (OCTOBER, 1946), PP. 1772-1778

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

RECENT PUBLICATIONS

ALASKA

*"Navy Has Ambitious Plans for Alaskan Oil Development," *anon. World Petroleum*, Vol. 17, No. 9 (New York, August, 1946), pp. 50–51; 4 photographs.

APPALACHIANS

"The Texture of Paleozoic Sandstones and Sandy Limestones in the Appalachian Basin," by Gordon Rittenhouse and Elaine Cather. *U. S. Geol. Survey* (August, 1946). Supplements earlier report by same authors, titled: "The Texture of Mississippian, Upper Devonian, and Lower Pennsylvanian Sandstone in the Appalachian Basin." Mimeogr. copies of both reports obtainable on request from Director, Geological Survey, Washington 25, D. C.

ARIZONA

*"The Structural Geology of the Dragoon Mountains, Arizona," by D. J. Cederstrom. *Amer. Jour. Sci.*, Vol. 244, No. 9 (New Haven, Connecticut, September, 1946), pp. 601–21; 1 outline map, 1 geologic map, geologic cross sections.

AUSTRALIA

*"Western Australia," by A. H. Telfer. *Oil Weekly*, Vol. 123, No. 1 (Houston, September 2, 1946), pp. 8–9; geologic map.

BRAZIL

*"Brazil's Oil Future Appears Bright," by S. Fróes Abreu. *Petroleo Interamericano*, Vol. 4, No. 9 (Petroleum Publishing Company, Tulsa, September, 1946), pp. 36–43; 2 sketch maps, 3 photographs, 5 geologic sections. In Spanish and English.

*"O Irati e suas relações com o problema do petróleo" (The Irati Formation and Its Relationship to the Problem of Petroleum), by Sylvio Fróes Abreu. *Mineração e Metalurgia*, Vol. 10, No. 60 (Rio de Janeiro, Brazil, May–June, 1946), pp. 267–79; 1 outline map, 14 photographs, tables. In Portuguese.

CALIFORNIA

"Geologic Map of Northeast Margin of San Gabriel Basin, Los Angeles County, California," by J. S. Shelton. *U. S. Geol. Survey Prelim. Map 63*, Oil and Gas Investig. Ser. (September, 1946). Single sheet, 40×46 inches. Scale, 1 inch equals 4,000 feet. Includes cross sections, an index map, a chart of drill-hole records, and brief text. For sale by Director, Geological Survey, Washington 25, D. C.

*"California Oil Well Gas Available to Gas Companies," by Ernest K. Parks. *California Oil World*, Vol. 39, No. 16, first issue (Los Angeles, California, August, 1946), pp. 5–11; 2 charts, 5 tables.

COLORADO

*"Rangely Field Geology and Development," by Bernard M. Bench. *Oil Weekly*, Vol. 123, No. 1 (Houston, September 2, 1946), pp. 18–25; 1 map, 6 photographs, 1 geologic section, 3 tables, bibliography.

FRANCE

*"Oil Prospecting and Natural Gas Utilisation in the South of France," by Marceau. *Petroleum*, Vol. 9, No. 8 (Leonard Hill Limited, London, W. I., England, August, 1946), pp. 180, 187; 2 figs.

GENERAL

*"Review of Petroleum Geology in 1945," by F. M. Van Tuyl and W. S. Levings, *et al. Quar. Colorado School of Mines*, Vol. 41, No. 3 (Golden, Colorado, July, 1946). 203 pp., 1 photograph, 2 figs. Sponsored by research committee of A.A.P.G. Price, $1.50 postpaid if payment accompanies order; otherwise $2.00 postpaid.

*"Related Trends in Future Domestic and Foreign Petroleum Operations," by Howard W. Page. *Petrol. Tech.*, Vol. 9, No. 4 (New York, July, 1946). 6 pp., 2 figs. *A.I.M.E. Tech. Pub. 2048.*

*"Interpretation of Well Test Data in Gas-Condensate Fields," by James O. Lewis. *Ibid.*, 23 pp., 15 figs., 2 tables. *A.I.M.E. Tech. Pub. 2053.*

*"Some Experiments on the Mobility of Interstitial Waters," by R. G. Russell, F. Morgan, and M. Muskat. *Ibid.* 11 pp., 4 figs., 4 tables. *A.I.M.E. Tech. Pub. 2054.*

*"A Factual Analysis of the Effect of Well Spacing on Oil Recovery," by R. C. Craze and S. E. Buckley. *Oil and Gas Jour.*, Vol. 45, No. 16 (Tulsa, August 24, 1946), pp. 97–116; 10 figs., 2 tables.

*"Well Logging Methods," by Hubert Guyod. *Petrol. Engineer*, Vol. 17, No. 12 (Dallas, August, 1946), pp. 62–66; 8 figs.

*"Importance of Research in Secondary Recovery by Water Flooding," by Richard V. Hughes. *Ibid.*, pp. 180–84; bibliography included.

*"Engineering Applications of Aerial Reconnaissance," by Donald J. Belcher. *Bull. Geol. Soc. America*, Vol. 57, No. 8 (New York, August, 1946), pp. 727–34; 6 pls., 2 figs.

*"Mineral Resources and Mineral Resourcefulness," by W. E. Wrather. *Min. and Met.*, Vol. 27, No. 475 (New York, August, 1946), pp. 427–29. Condensation of address before Colorado Mining Association, Denver, January 25, 1946.

*"Petroleum Reserves Continue to Decline as Peacetime Use Exceeds Predictions," by William B. Heroy. *Ibid.*, pp. 429–31. Address before Chamber of Commerce of United States, Atlantic City, May 2, 1946.

*"Geology Applied to Petroleum. Part 2, Types of Regional Structure," by Vincent C. Illing. *Oil Weekly*, Vol. 122, No. 13 (Houston, August 26, 1946), pp. 30–33, 37; 2 figs., 1 outline map.

*"Oil Shale—America's Fuel Ace in the Hole," Anon. As seen by the U. S. Bureau of Mines. *Oil Weekly*, Vol. 45, No. 17 (Houston, August 31, 1946), pp. 68–69, 97–100; 1 sketch map, 7 photographs.

*"Proceedings of Conference on Training in Geology." *Interim Proc. Geol. Soc. America*, Pt. 5 (New York, July, 1946). 26 pp. Conference called by National Research Council Committee under auspices of American Geophysical Union, George Washington University, May 28, 1946, Washington, D. C.

*"Geology Applied to Petroleum. Part 3, Types of Regional Structure," by Vincent C. Illing. *Oil Weekly*, Vol. 123, No. 1 (Houston, September 2, 1946), pp. 27–29, 32; 1 sketch map, 1 photograph, 3 geologic sections.

*"Geology Applied to Petroleum. Part 4, Oil Recovery and Exploration," by Vincent C. Illing. *Ibid.*, Vol. 123, No. 2 (September 9, 1946), pp. 39–44; 3 photographs.

*"Geology Applied to Petroleum. Part 5 (Conclusion), Influence of Oil on Geology," by Vincent C. Illing. *Ibid.*, Vol. 123, No. 3 (September 16, 1946), pp. 174–76; 1 photograph.

*"Mathematical Methods of Decline Curve Extrapolation and Reserve Calculation,"

by Sylvain J. Pirson. *Oil Weekly*, Vol. 123, No. 2 (Houston, Texas, September 9, 1946), pp. 45–59; 6 figs., 3 tables.

Industrial Research Laboratories of the United States, eighth edition (1946). 400 pp. Data on 2,443 industrial research laboratories; indexed with respect to personnel, geographical location, and research activities. Published by Publications Office, National Research Council, 2101 Constitution Avenue, Washington 25, D. C.

*"Cryopedology—The Study of Frozen Ground and Intensive Frost-Action with Suggestions on Nomenclature," by Kirk Bryan. *Amer. Jour. Sci.*, Vol. 244, No. 9 (New Haven, Connecticut, September, 1946), pp. 622–42; 4 figs., bibliography.

*"The Clay Content of Oil Sands," by T. F. Bates, R. M. Gruver and S. T. Yuster. *Producers Monthly*, Vol. 10, No. 10 (Bradford, Pennsylvania, August, 1946), pp. 16–19; 5 figs.

*"Validity of Data from Airborne Magnetometer," by Homer Jensen. *World Petroleum*, Vol. 17, No. 9 (New York, August, 1946), p. 45; 1 photograph.

Oil and Petroleum Year Book, revised edition (1946), compiled by Walter E. Skinner. 200 pp. An international reference book devoted to oil companies, producers, refiners, transporters, *et cetera*. 5.5×8.2 inches, cloth. Published by Walter E. Skinner, 20, Copthall Avenue, London, E. C. 2. Price, postpaid: 15 s. 6 d. (Abroad, 16s.).

*"Marine Solution Basins," by K. O. Emery. *Jour. Geol.*, Vol. 54, No. 4 (University of Chicago Press, Chicago, Illinois, July, 1946), pp. 209–28; 15 figs., 4 tables.

GEORGIA

*"Geology of the Coastal Plain of East-Central Georgia," by Philip E. LaMoreaux. *Georgia Geol. Survey Bull. 50*, Pt. 1 (Atlanta, 1946). 26 pp., 1 pl., 8 figs.

*"Progress of Oil Search in Georgia," by Garland Peyton. *Oil Weekly*, Vol. 123, No. 3 (September 16, 1946), pp. 92–96; generalized geologic map, geologic cross section.

GULF COAST

*"The Mollusca of the Jackson Eocene of the Mississippi Embayment (Sabine River to the Alabama River)," by Gilbert D. Harris and Katherine Van Winkle Palmer, *Bulletins of Amer. Paleontology*, Vol. 30, No. 117, 1st Sec. (August 3, 1946). 206 pp., 25 pls. Paleontological Research Institution, Ithaca, New York.

*"Highlights of Gulf Coast Development," by James S. Critz. *Oil Weekly*, Vol. 123, No. 3 (Houston, Texas, September 16, 1946), pp. 81–88; outline maps showing largest oil fields in Upper Texas Gulf Coast and Louisiana Gulf Coast oil fields, table showing cumulative production and estimated reserve of Gulf Coast oil fields. Insert map, scale, 1 inch equals 13 miles, gives names and locations of oil, gas, and condensate fields of Texas-Louisiana Gulf Coast region.

*"Development, Trends in Salt Dome Exploration," by Cecil Hagen and Ralph Cantrell. *Ibid.*, pp. 87–88; idealized cross section of a salt dome.

*"What's Wrong With the Eastern Gulf Coast?" by John D. Todd. *Ibid.*, pp. 89–91; generalized geologic map and correlation chart of probable producing formations.

*"Gulf Coast Oil Fields. Geologic Data, Development History," compiled by James S. Critz. *Ibid.*, pp. 106–59. Includes data on discovery, structure, producing formation, production, gravity, deepest zone tested, principal leaseholders. Indexed by counties, parishes, and fields.

INDIA

"Second Symposium on the Age of the Saline Series in the Salt Range of the Punjab," by many authors. *Proc. Natl. Academy of Sciences, India, 1945*, Vol. 16, Sec. B, Pts. 1 and 2. Published by the Council, Allahabad, India (1946). Symposium held at Udaipur

on December 27 and 28, 1945, under joint auspices of the National Academy and the Indian Academy of Sciences. Approx. 200 pp., illustrated with photographs, text figures, geological maps, sections, and tables. Separate copies for sale by the General Secretary, National Academy of Sciences, c/o Department of Botany and Geology, University of Lucknow, U. P., India. Price, Rs. 12/8 (India), Rs. 15/– (Abroad).

The Saline Series in the Salt Range: Is It Cambrian or Tertiary? by B. Sahni (Lucknow)
Note on Cores from a Borehole in the Mayo Salt Mine, Khewra, by B. S. Lamba (Khewra)
Comments on the First Symposium on the Age of the Saline Series, by L. L. Fermor (Bristol)
Age and Origin of the Salt Deposits of North-West India, by L. M. Davies (Edinburgh)
Some Fossil Arthropods from the Saline Series in the Salt Range, by M. S. Mani (Agra)
A Reconsideration of the Nappe in Mandi and the Probable Age of the Salt, by K. K. Dar (Delhi)
Some Tectonic Aspects of the Problem, by E. Lehner (Buchillon)
A Note on the Saline Series of North-Western India, by M. S. Krishnan and N. K. N. Aiyengar (Madras)
Search for Microfossils in the Purple Sandstone, Khewra Gorge, by F. Hsu (Lucknow)
Further Note on the Age of the Saline Series of the Punjab and of Kohat, by E. R. Gee (Calcutta)
Microfossils from Cores Recovered from Boreholes at Khewra, by R. N. Lakhanpal (Lucknow)
Evidence for Eocene Age of Saline Formation beneath Salt Range Thrust, by R. van V. Anderson (Stanford University)
Further Notes on the Age of the Salt Range Saline Series, by E. S. Pinfold (Rawalpindi)
On Microfossils from the Saline Series, by B. S. Trivedi (Lucknow)
The Age of the Punjab Saline Series. A Review, by L. Rama Rao (Bangalore)
Microfossils from Some Oil-Shales in the Saline Series, by R. V. Sitholey (Lucknow)
Note on the Age of the Saline Series, by K. K. Dar (Delhi)
The Significance of Thrust Structure of the Salt Range, by D. N. Wadia (New Delhi)
Comments on the Salt Range Symposium, by F. V. Harrison (Oxford)

ITALY

*"Miocene Submarine Disturbances of Strata in Northern Italy," by C. Beets. *Jour. Geol.*, Vol. 54, No. 4 (Chicago, Illinois, July, 1946), pp. 229–45; 7 figs.

MISSISSIPPI

*"Lee County Mineral Resources," by Franklin E. Vestal. *Mississippi State Geol. Survey Bull. 63* (University, Mississippi, 1946). 140 pp., 19 figs., 3 plates. Stratigraphy, paleontology, structure, and economic geology of Lee County. 6×9 inches, paper cover.

MISSOURI

*"Missouri—Its Oil and Gas Possibilities," by Frank C. Greene. *Oil Weekly*, Vol. 123, No. 2 (Houston, Texas, September 9, 1946), pp. 34–46; 1 index map, 1 structure map, 1 geologic cross section.

MONTANA

"Structure Contour Map of the Montana Plains," by C. E. Dobbin and C. E. Erdmann. *U. S. Geol. Survey*, revision of 1932 and 1935 editions (August, 1946). Scale, 1 inch equals 8 miles. Obtainable from Director, Geological Survey, Washington 25, D. C. Price, $0.25.

NEW MEXICO

"Stratigraphic Relations of Eocene, Paleocene, and Latest Cretaceous Formations of Eastern Side of San Juan Basin, New Mexico," by C. H. Dane. *U. S. Geol. Survey Prelim. Chart 24*, Oil and Gas Investig. Ser. (August, 1946). Single sheet, 30×42 inches. For sale by Director, U. S. Geological Survey, Washington 25, D. C. Price, $0.35.

"Geologic Maps of a Part of the Las Vegas Basin and of the Foothills of the Sangre de Cristo Mountains, San Miguel and Mora Counties, New Mexico," by S A. Northrup, H. H. Sullwold, Jr., A. J. McAlpin, and C. P. Rogers, Jr. *U. S. Geol. Survey Prelim. Map 54*, Oil and Gas Investig. Ser. (August, 1946). Single sheet, 44×49 inches. One map, scale 1 inch equals 4 miles, shows the geology of a part of the Las Vegas basin; a larger map, scale 1½ inches equals 1 mile, shows in more detail the geology of the foothills region of the Sangre de Cristo Mountains. Geologic cross sections, an index map, and brief text included. For sale by Director, U. S. Geological Survey, Washington 25, D. C.; Room 314, Boston Building, Denver, Colorado; Room 234, Federal Building, Tulsa, Oklahoma. Price, $0.60.

"Geology of the Nacimiento Mountains, San Pedro Mountain, and Adjacent Plateaus in Parts of Sandoval and Rio Arriba Counties, New Mexico," by S. A. Northrop and Gordon H. Wood, Jr. *U. S. Geol. Survey Prelim. Map. 57*, Oil and Gas Investig. Ser. (September, 1946). Single sheet, 40×64 inches. Includes geologic map, scale 1 inch equals 1½ miles; 5 graphic sections; structure sections; 3 thickness maps; an index map; and brief text. For sale by Director, Geological Survey, Washington 25, D. C. Price, $0.60.

OKLAHOMA-TEXAS

"Mineral Resources of the Trinity River Tributary Area in Texas and Oklahoma," in 2 parts, compiled by the U. S. Geological Survey and the Texas Bureau of Economic Geology. Summarizes all available published data concerning the mineral fuels, metallic, and nonmetallic mineral resources in an area of 184,000 square miles of territory in the two states. Report prepared for Corps of Engineers, U. S. Army. Copies on open file for inspection at U. S. Geological Survey Library, Washington, D. C.; Bureau of Economic Geology, University of Texas, Austin, Texas; Office of Director, Oklahoma Geological Survey, Norman, Oklahoma; Trinity Improvement Association, 1308 Commercial Standard Building, Fort Worth, Texas; Chamber of Commerce, Dallas, Texas; Post Offices at Liberty, Texas, and Crockett, Texas.

PACIFIC ISLANDS

*"Coral Reefs in the Gilbert, Marshall, and Caroline Islands," by L. E. Nugent, Jr. *Bull. Geol. Soc. America*, Vol. 57, No. 8 (New York August, 1946), pp. 735–80; 2 pls., 15 figs.

PENNSYLVANIA

*"Origin of the Lackawanna Basin, Pennsylvania," by Bradford Willard. *Jour. Geol.*, Vol. 54, No. 4 (Chicago, Illinois, July 1946), pp. 246–51; 4 figs.

POLAND

The following Bulletins have been received from the Geological Survey of Poland, Karol Bohdanowicz, director, Warsaw, Poland.

*"Structure geólogique des Karpates dans la région de Dynów," by Jan Wdowiarz. *Institut Geol. Pologne Bull. 10* (Warsaw, 1939). 20 pp. in Polish; resumé (pp. 21–24) in French. 2 pls., 1 fig.

*"Compte-rendu des travaux géologiques exécutés en 1938 dans le Massif de Ste. Croix en Volhynie et en Polésie" (Reports of Geological Work in 1938 in the Massif of Ste. Croix

in Volhynia and Polesia), by 8 authors. *Ibid., Bull. 15* (1939). 16 papers in Polish, with summaries in English and French.

*"Contributions a la géologie de la Pologne in 1938–1939," by 6 authors. *Ibid., Bull. 17* (1939). 6 papers in Polish, each with brief summary in German or French. 31 pp., 3 figs., 1 pl.

*"Activité de l'Institut Geologique de Pologne en 1938." *Ibid., Bull. 18* (1939). Miscellaneous reports. 134 pp., 17 pls., 13 figs. In Polish.

*"Champ de gaz de Sadkowa-Roztoki-Sobniów" (Oil and gas fields), by Henryk Swidzinski and Józef Zwierzycki. *Ibid., Bull. 20* (1939). 11 pp., 10 pls. In Polish.

*"Petrographic Investigations of the Boghead Coal from the Radzionków Mine, Upper Silesia," by Adam Drath. *Ibid., Bull. 21* (1939). 82 pp., 15 pls., 6 figs. In Polish; summary in English.

SOUTH AMERICA

*"Oil Possibilities in Nonproducing Countries of South America," by Victor Oppenheim. *Petroleo Interamericano*, Vol. 4, No. 9 (Petroleum Publishing Company, Tulsa, September, 1946), pp. 53–57; outline map of the Tertiary Basins and Oil Fields of South America. A condensation of "Geologic Outline of South American Oil Fields," by Victor Oppenheim, to be published by the United States section of the Pan American Institute of Mining Engineers and Geology. In Spanish and English.

TENNESSEE

*"Subsurface Stratigraphy and Structure of the Pre-Trenton Ordovician and the Upper Cambrian Rocks in Central Tennessee," as of 1945, by Ray Bentall and Jack B. Collins. *U. S. Geol. Survey Prelim. Chart 4*, Oil and Gas Investig. Ser. (August,1946). 2 sheets, 56×36 inches. 2 structural maps, 3 thickness maps; scale, 1 inch equals 16 miles. 4 stratigraphic sections; scale, 1 inch equals 200 feet. 2 index maps, 1 correlation chart, 1 table of well data, descriptive text, and bibliography. For sale by Director, Geological Survey, Washington 25, D. C., and Tennessee Division of Geology, G-5 State Office Building, Nashville 3, Tennessee.

TEXAS

*"TXL Is Representative of New Pre-Permian Fields; Promises Major Reserve," by George Weber. *Oil and Gas Jour.*, Vol 45, No. 16 (Tulsa, August 24, 1946), pp. 81–84, 122; 3 figs.

*"Operators in Hull and Silk Field Study Repressuring Program," by C. H. Keplinger and J. M. Wanenmacher. *Oil Weekly*, Vol. 45, No. 17 (Houston, August 31, 1946), pp. 76–84; 3 figs.

*"The Panhandle Field: the World's Largest Natural Gas Reserve," by E. G. Dahlgren. Reprinted from *Gas* (July, 1946), pp. 44–51; 1 photograph, 4 figs., 7 tables.

UTAH

"Section of Morgan Formation, Pennsylvanian, at Split Mountain in Dinosaur National Monument, Uintah County, Utah," by Franklin T. McCann, Norman D. Raman, and Lloyd G. Henbest. *U. S. Geol. Survey* (August, 1946). Mimeogr. text and graphic section may be obtained from Director, Geological Survey, Washington 25, D. C. Free.

*"The San Juan Oil Field of Southeastern Utah, Lies to Northwest of San Juan Basin Field of Northwestern New Mexico," by Ray E. Colton. *California Oil World*, Vol. 39, No. 15 (Los Angeles, August 15, 1946), pp. 3–7, 32; 2 figs.

VENEZUELA

*"Geology of the Maracaibo Basin, Part 1," by F. A. Sutton. *Petroleo Interamericano*,

Vol. 4, No. 9 (Petroleum Publishing Company, Tulsa, September, 1946), pp. 45–47, 67–68, 72; 2 sketch maps, 1 photograph, 2 charts, 2 tables. In Spanish and English. The complete paper is published in English in this issue of the Bulletin.

*"Exploration of Orinoco Delta Fraught With Difficulties of Terrain and Climate," by Paul Reed, *Oil and Gas Jour.*, Vol. 48, No. 19 (Tulsa, Oklahoma, September 14, 1946), pp. 64–66; 1 sketch map, 4 photographs.

WEST VIRGINIA

Well-Sample Records, by James H. C. Martens. West Virginia Geol. Survey, Vol. 17. 889 pp. Detailed description of drill cuttings from over 300 wells drilled for oil and gas in, or adjacent to, West Virginia. Formations represented range in age from the Knox dolomite of Ordovician age to the Dunkard group of Permian age. All but five of the wells from which samples were studied were drilled with cable tools. Sample descriptions are based on laboratory examination employing a low-power binocular microscope. Volume contains a complete list of samples in the Survey's collection from 736 wells, including those described in Vol. 11. 6×9.25 inches, cloth. Published by the West Virginia Geological Survey, Morgantown, West Virginia (June 30, 1945).

WYOMING

"Geologic Map of the Southern Part of the Wind River Basin and Adjacent Areas in Central Wyoming," by C. J. Hares, M. W. Ball, Stuart St. Clair, J. B. Reeside, Jr., K. C. Heald, and A. C. Collins. *U. S. Geol. Survey Prelim. Map 60*, Oil and Gas Inves. Ser. (August, 1946). Originally prepared on basis of field work in 1913–1914. Sheet 28×32 inches. For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.30.

*"Guide Book, First Annual Field Conference of the Wyoming Geological Association. Central and Southeastern Wyoming." 57 pp., 1 reconnaissance sketch map showing serial geology, 4 route maps, 1 geologic map, 4 photographs, 18 geologic sections, 4 electrical logs. Guide book of field conference conducted, August 7–10, 1946, by the Wyoming Geological Association, with the assistance of the department of geology, University of Wyoming, and the Geological Survey of Wyoming. Published by the Wyoming Geological Association, Casper, Wyoming (1946).

DIVISION OF PALEONTOLOGY AND MINERALOGY

* *Journal of Paleontology* (Tulsa, Oklahoma), Vol. 20, No. 5 (September, 1946)

"Corals of the Independence Shale of Iowa," by Merrill A. Stainbrook
"Upper Aptian Nautiloids from Colombia," by J. Wyatt Durham
"*Plemnocrinus*, a New Crinoid Genus from the Lower Mississippian," by Edwin Kirk
"Early Upper Cambrian Trilobites from Western Gaspé," by Franco Rasetti
"*Siphogenerinoides* Cushman (Order Foraminifera, Family Buliminidae)," by Benton Stone
"A Giant Ammonite from the Cretaceous of Montana," by A. K. Miller and Walter Youngquist
"Late Tertiary Fresh-water Mollusks from Southeastern Idaho," by Teng-Chien Yen
"Eocene Nonmarine Gastropods from Hot Spring County, Wyoming," by Teng-Chien Yen
"Orientation of the Crystal Units of Conodonts," by Wilbert H. Hass and Marie L. Lindberg
"A Lower Cretaceous Fauna in the Northwest Basin of Western Australia," by Irene Crespin
"Check List of the Fossil Fishes of New Jersey," by William F. Rapp, Jr.
"Optimum Conditions for the Photography of Fossils," by Franco Rasetti

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 10 (OCTOBER, 1946), PP. 1779–1785

THE ASSOCIATION ROUND TABLE

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

EARL B. NOBLE, *chairman*, Union Oil Company of California, Los Angeles, California
EDWARD A. KOESTER, *secretary*, Darby & Bothwell, Wichita, Kansas
MONROE G. CHENEY, Anzac Oil Corporation, Coleman, Texas
D. PERRY OLCOTT, Humble Oil and Refining Company, Houston, Texas
GAYLE SCOTT, Texas Christian University, Fort Worth, Texas

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL: PHILIP B. KING (1949)

REPRESENTATIVES ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

CARROLL E. DOBBIN — ROBERT J. RIGGS

REPRESENTATIVES ON COMMISSION ON CLASSIFICATION AND NOMENCLATURE OF ROCK UNITS

M. G. CHENEY (1947), *chairman* — JOHN G. BARTRAM (1948) — WAYNE V. JONES (1949)

STANDING COMMITTEES

FINANCE COMMITTEE

FRANK R. CLARK (1947), *chairman* — JOSEPH E. POGUE (1948) — JOHN S. IVY (1949)

TRUSTEES OF REVOLVING PUBLICATION FUND

W. D. KLEINPELL (1947), *chairman* — W. B. WILSON (1948) — WILLIAM B. HEROY (1949)

TRUSTEES OF RESEARCH FUND

E. O. MARKHAM (1947), *chairman* — T. S. HARRISON (1948) — ROBERT W. CLARK (1949)

BUSINESS COMMITTEE

C. L. MOODY (1947), *chairman*, Ohio Oil Company, Shreveport, Louisiana

A. P. ALLISON (1947)
WARREN D. ANDERSON (1948)
E. J. BALTRUSAITIS (1947)
FRANK W. BELL (1948)
JOSEPH L. BORDEN (1947)
MAX BORNHAUSER (1947)
IRA H. BRINKERHOFF (1948)
MONROE G. CHENEY (1947)
H. E. CHRISTENSEN (1948)
FRANK R. CLARK (1948)
CARLE H. DANE (1948)
ADOLPH DOVRE (1947)
ROLLIN ECKIS (1947)
STANLEY G. ELDER (1948)
ROBERT M. ENGLISH (1947)
GLENN C. FERGUSON (1947)
GEORGE R. GIBSON (1947)
WESLEY G. GISH (1948)
W. DOW HAMM (1948)
GLENN D. HAWKINS (1947)
L. W. HENRY (1947)
J. S. HUDNALL (1947)
EDWIN H. HUNT (1947)
JOHN W. INKSTER (1947)
ROBERT L. KIDD (1948)
EDWARD A. KOESTER (1947)
CLAUDE E. LEACH (1948)
PAUL B. LEAVENWORTH (1947)
LYNN K. LEE (1947)
SHIRLEY L. MASON (1948)
GAIL F. MOULTON (1947)
JERRY B. NEWBY (1947)
EARL B. NOBLE (1948)
P. H. O'BANNON (1948)
D. PERRY OLCOTT (1947)
ELISHA A. PASCHAL (1948)
F. W. ROLSHAUSEN (1947)
J. J. RUSSELL, JR. (1948)
GAYLE SCOTT (1947)
ROBERT L. SIELAFF (1947)
IRA H. STEIN (1947)
HENRYK B. STENZEL (1947)
D. E. TAYLOR (1948)
G. D. THOMAS (1948)
HENRY N. TOLER (1947)
C. W. TOMLINSON (1948)
GEORGES VORBE (1947)
W. O. ZIEBOLD (1947)

COMMITTEE FOR PUBLICATION

LYNN K. LEE (1948), *chairman*, Pure Oil Company, Fort Worth, Texas

1947	1948	1949
J. E. BILLINGSLEY	JOSEPH L. BORDEN	JOHN G. GRAY
DON O. CHAPELL	W. H. HOFFMEISTER	GEORGE C. GROW
J. I. DANIELS	J. M. KIRBY	BENJAMIN F. HAKE
HOLLIS D. HEDBERG	E. RUSSELL LLOYD	MASON L. HILL
LEE C. LAMAR	HOMER A. NOBLE	GEORGE S. HUME
E. A. PASCHAL	THOMAS F. STIPP	JAMES A. MOORE
K. K. SPOONER	C. W. WILSON, JR.	ROBERT B. NEWCOMBE
T. E. WEIRICH		E. A. WENDLANDT

RESEARCH COMMITTEE

SHEPARD W. LOWMAN (1947), *chairman*, Shell Oil Company, Houston, Texas

1947	1948	1949
E. R. ATWILL	RONALD K. DEFORD	WALTER R. BERGER
ROLAND F. BEERS	MARCUS A. HANNA	K. C. HEALD
PARKE A. DICKEY	W. P. HAYNES	WILLIAM C. IMBT
G. C. GESTER	MARSHALL KAY	W. C. KRUMBEIN
ROBERT N. KOLM	PHILIP B. KING	F. M. VAN TUYL
GRAHAM B. MOODY	A. I. LEVORSEN	W. A. WALDSCHMIDT
D. PERRY OLCOTT	W. W. RUBEY	
ROBERT J. RIGGS	W. T. THOM, JR.	
JOSEPH A. SHARPE		

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

HENRY J. MORGAN, JR. (1948), *chairman*, Atlantic Oil and Refining Company, Dallas, Texas

1947	1948	1949
STUART K. CLARK	JOHN G. BARTRAM	ROLLIN ECKIS
ROY T. HAZZARD	ROBERT H. DOTT	G. D. THOMAS
W. J. HILSEWECK	E. FLOYD MILLER	H. D. THOMAS
WAYNE V. JONES	HUGH D. MISER	L. E. WORKMAN
W. ARMSTRONG PRICE	RAYMOND C. MOORE	

SUB-COMMITTEE ON CENOZOIC

W. ARMSTRONG PRICE (1947), *chairman*, Box 1860, Corpus Christi, Texas

GORDON I. ATWATER	HENRY V. HOWE	TOM MCGLOTHLIN
B. W. BLANPIED	WAYNE V. JONES	PHILIP S. MOREY
MARCUS A. HANNA		E. A. MURCHISON, JR.

SUB-COMMITTEE ON MESOZOIC

G. D. THOMAS (1949), *chairman*, Shell Oil Company, Shreveport, Louisiana

C. I. ALEXANDER	L. R. MCFARLAND	ROBERT L. SIELAFF
RALPH W. IMLAY	E. H. RAINWATER	JAMES D. WEIR
W. D. KLEINPELL	J. R. SANDIDGE	RICHARD M. WILSON
	GAYLE SCOTT	

SUB-COMMITTEE ON PALEOZOIC

ROBERT H. DOTT (1948), *chairman*, Oklahoma Geological Survey, Norman, Oklahoma

STUART K. CLARK	E. FLOYD MILLER	RAYMOND C. MOORE
W. J. HILSEWECK	HUGH D. MISER	

COMMITTEE ON APPLICATIONS OF GEOLOGY

KENNETH K. LANDES (1947), *chairman*, University of Michigan, Ann Arbor, Michigan

1947	1948	1949
LEO R. FORTIER	ROBERT I. DICKEY	E. M. BAYSINGER
THOMAS A. HENDRICKS	CHARLES R. FETTKE	CHARLES J. DEEGAN
W. T. NIGHTINGALE	OLAF P. JENKINS	L. B. HERRING
PAUL WEAVER	NICHOLAS A. ROSE	R. A. STEHR

MEDAL AWARD COMMITTEE

EARL B. NOBLE, *chairman*, Union Oil Company, Los Angeles, California
F. W. ROLSHAUSEN, *ex officio*, president of S.E.P.M.
J. J. JAKOSKY, *ex officio*, president of S.E.G.

1947	1948	1949
H. B. FUQUA	A. RODGER DENISON	RUSSELL S. MCFARLAND
THORNTON DAVIS	VIRGIL B. COLE	RAYMOND F. BAKER
HUGH D. MISER	J. EDMUND EATON	C. R. MCCOLLOM

COMMITTEE ON STATISTICS OF EXPLORATORY DRILLING

F. H. LAHEE (1947), *chairman*, Sun Oil Company, Box 2880, Dallas, Texas
PAUL WEAVER (1948), *vice-chairman*, Gulf Oil Corporation, Box 2100, Houston, Texas

1947	1948	1949
ALFRED H. BELL	KENNETH COTTINGHAM	ROBERT L. BATES
R. J. CULLEN	RALPH E. ESAREY	STANLEY G. ELDER
W. LLOYD HASELTINE	FENTON H. FINN	COLEMAN D. HUNTER
W. J. HILSEWECK	JOHN W. INKSTER	ROBERT C. LAFFERTY, JR.
W. S. MCCABE	GRAHAM B. MOODY	D. J. MUNROE
JOHN C. MILLER	CHARLES H. ROW	T. F. PETTY
C. L. MOODY		GLENN C. SLEIGHT
		C. W. WILSON

DISTINGUISHED LECTURE COMMITTEE

FRED H. MOORE, *chairman*, Magnolia Petroleum Company, Mt. Vernon, Illinois

1947	1948	1949
LEE H. CORNELL	EVERETT F. STRATTON	HUGH R. BRANKSTONE
JOHN L. FERGUSON	CARROLL M. WAGNER	
W. J. HILSEWECK		

SPECIAL COMMITTEES

NATIONAL SERVICE COMMITTEE

M. GORDON GULLEY, *chairman*, Gulf Oil Corporation, Pittsburgh, Pennsylvania

FRITZ L. AURIN	CHARLES B. HUNT	ED. W. OWEN
OLIN G. BELL	OTTMAR F. KOTICK	W. T. SCHNEIDER
CHARLES E. ERDMANN	LAWRENCE E. NUGENT, JR.	

COMMITTEE ON BOY SCOUTS LITERATURE

MAX W. BALL, *chairman*, Denver National Bank Building, Denver, Colorado

A. C. BACE	DON L. CARROLL

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Arthur Cecil Austin, Tulsa, Okla.
John M. Ware, V. L. Frost, Frank R. Clark
Thomas Armet Baldwin, Los Angeles, Calif.
J. M. Hamill, R. E. Baddley, James R. Dorrance
Thomas Reed Barnes, Los Angeles, Calif.
Frank S. Parker, E. F. Davis, M. G. Edwards
Roy Francis Bennett, Houston, Tex.
George S. Buchanan, George I. McFerron, John P. Smoots
James Donald Forrester, Rolla, Mo.
K. F. Hasselmann, C. H. Summerson, Allen R. Ostrander
Oscar Kenneth Fuller, Jr., Pasadena, Calif.
C. Hewitt Dix, Herbert Hoover, Jr., Barthold W. Sorge
Jack Ogilvie Horton, Caracas, Venezuela, S. A.
Norman E. Weisbord, E. Mencher, F. I. Martin
Nelson H. James, Houson, Tex.
Merle C. Israelsky, George U. McFerron, George S. Buchanan
Gustave John Kohler, Jr., Dallas, Tex.
H. B. Peacock, Cecil H. Green, James W. Thomas
Charles M. Linehan, Wichita Falls, Tex.
R. L. Cannon, William N. Mosher, E. Russell Lloyd
Geoffrey Ross Lucie-Smith, Cairo, Egypt
Louis G. Millward, A. T. Schwennesen, David T. Hoenshell
Rudolf Muhlemann, Caracas, Venezuela, S. A.
H. G. Kugler, H. H. Suter, F. W. Penny
Irvin Bernard Murray, Jr., Houston, Tex.
F. X. Bostick, Harold S. Kemp, Leonard J. Neuman
Stephen Burdette Powell, Wichita, Kan.
John W. Inkster, Victor F. Reiserer, Emmett R. Elledge
Charles W. Prewett, Los Angeles, Calif.
George C. Kuffel, D. E. Taylor, Lee S. Osborne
Jean William Schroeder, Paris, France
E. A. Ritter, L. Vonderschmitt, H. de Cizancourt
Alfred Neeld Sharrick, Wichita, Kan.
John W. Inkster, G. S. Lambert, T. C. Peters
Herbert Lee Spyres, Jackson, Miss.
Frederic F. Mellen, R. A. Rank, L. D. Bartell
Charles Emile R. Thiebaud, Caracas, Venezuela, S.A.
L. Kehrer, J. J. Dozy, J. B. Woolley
Donald Desmond Utterback, New Orleans, La.
Harluf C. Petersen, B. E. Bremer, Gordon I. Atwater

FOR ASSOCIATE MEMBERSHIP

Margaret Jayne Applegate, Ann Arbor, Mich.
R. C. Hussey, Kenneth K. Landes, Lewis B. Kellum
Orville Lee Bandy, Houston, Tex.
Ralph Esarey, E. P. Tatum, R. D. Woods
Allen Milton Borland, Port Neches, Tex.
Frederick A. Burt, Harold Vance, F. E. Turner
Ray Albert Burke, Elgin, Tex.
L. C. Snider, Fred M. Bullard, F. L. Whitney
Joseph M. Burton, Houston, Tex.
Lon D. Cartwright, Jr., W. D. Keller, E. B. Branson
Alvin A. Candela, Galveston, Tex.
Hal P. Bybee, Fred M. Bullard, F. L. Whitney
Keegan Carter, Laurel, Miss.
C. W. Alexander, M. E. Norman, Tom McGlothlin
Stuart Lyle Carter, Denver, Colo.
A. W. Cullen, A. E. Brainerd, Charles S. Lavington
Waldemar M. Dressel, Midland, Tex.
James S. Cullison, Samuel P. Ellison, Jr., Garrett A. Muilenburg
Jane Brite Dunkle, Marfa, Tex.
Hal P. Bybee, Fred M. Bullard, G. K. Eifler, Jr.
George Harold Feister, Los Angeles, Calif.
E. K. Soper, Cordell Durrell, James Gilluly
Robert Howard Glover, Cordell, Okla.
Thomas W. Koch, Louis S. Wallace, Frank Ittner
Edward Albert Gribi, Jr., Stanford, Calif.
F. G. Tickell, Eliot Blackwelder, George L. Harrington
Walter Frederick Hamilton, Shreveport, La.
J. R. Williams, W. C. Spooner, B. W. Blanpied
Carl Hobe, Fresno, Calif.
L. S. Chambers, V. W. Vandiver, Downs McCloskey
Node William Johns, New Orleans, La.
Neal J. Smith, F. E. Turner, J. W. Hoover
James Kendall Johnston, San Antonio, Tex.
Vernon E. Guffey, William W. Henry, Noel H. Stearn
John Zay Kimberlin, Graford, Tex.
Berte R. Haigh, H. A. Hemphill, Russell C. Conkling
Manuel Nieva Mayuga, Los Angeles, Calif.
J. M. Hamill, Boris Laiming, Paul P. Goudkoff
Jack Angus Menish, Midland, Tex.
Charles F. Henderson, Ludvig C. Lindeblad, W. C. Imbt
William Rinehart Miller, Dallas, Tex.
Hal P. Bybee, L. C. Snider, F. L. Whitney
Ramsey LeBleu Oakes, Leesville, La.
Richard Joel Russell, Rufus K. Le Blanc, Chalmer J. Roy
James Allen Otts, Jr., Laurel, Miss.
Roy T. Hazzard, C. W. Alexander, Tom McGlothlin
Lavon Marie Peters, Midland, Tex.
Eugene A. Stephenson, Harold L. Williams, William J. Hilseweck

Albert Charles Raasch, Jr., Houston, Tex.
R. D. Woods, E. P. Tatum, F. W. Rolshausen
Edith Jean Richards, Midland, Tex.
John Paul Gries, Jackson M. Barton, Kenneth K. Landes
Fernando Bernardino Saguier, Los Angeles, Calif.
Max Krueger, E. B. Noble, William F. Cerini
Warren Barrett Scobey, Midland, Tex.
Jackson M. Barton, Jane Ferrell, John Paul Gries
Clay Luzenberg Seward, Jr., Brenham, Tex.
J. Brian Eby, Frederick A. Burt, F. E. Turner
John A. Vary, Grand Rapids, Mich.
Max W. Ball, Paul B. Whitney, H. D. Crider
Edwin James Webb, Pittsburgh, Pa.
R. E. Somers, H. R. Brankstone, W. B. Gealy
Charles R. Wilcox, Mt. Vernon, Ill.
Fred H. Moore, T. E. Wall, Rex Grant

FOR TRANSFER TO ACTIVE MEMBERSHIP

William Hammond Allen, Midland, Tex.
Robert E. King, V. W. Rogers, Bernerd A. Ray
John Edward Brewer, Wichita, Kan.
Clark T. Snider, Walter A. Ver Wiebe, George D. Putnam
Henry Andrew Campo, Shawnee, Okla.
A. M. Meyer, W. H. Butt, R. A. Brant
Sam Russel Casey, Jr., Houston, Tex.
E. M. Funkhouser, John S. Ivy, Buford Miller
Paul Woodward Foster, Houston, Tex.
E. A. Markley, J. D. Hedley, H. L. Geis
Frederick Henry Kate, Oklahoma City, Okla.
H. E. Rankin, Dean C. Wellman, Gerald C. Maddox
Robert McMillan, Denver, Colo.
L. Brundall, C. E. Dobbin, A. R. Wasem
Joe Hiram Moore, Hobbs, N. Mex.
R. L. Boss, John R. McMillan, Robert E. LeBlond
Virginia Marcelle Mousley, Shawnee, Okla.
A. M. Meyer, Delbert F. Smith, Allen W. Tillotson
T. Dean Mundorf, Glasgow, Mont.
W. R. Longmire, W. I. Ingham, Clyde O. Hudgens
James Moulton Whatley, Sulphur, La.
James A. Moore, Harry Kilian, George N. May

MID-CONTINENT REGIONAL MEETING
WICHITA, KANSAS, JANUARY 16–17, 1947

The Kansas Geological Society has invited the A.A.P.G. to hold a Mid-Continent regional meeting at Wichita, Kansas, on January 16 and 17, 1947, and the executive committee of the Association has accepted. The Broadview Hotel is to be headquarters. With the motto, "Looking Backward, then Forward," the program committee has chosen two themes for the technical papers: "Unusual Oil Fields" and "Future Possibilities of the Mid-Continent Region." The latter will include papers of the regional structural features, including the Anadarko basin, eastern Colorado, far western Kansas, possibly the Dakotas and Nebraska.

A dance is planned for the first night, January 16.

The officers of the Kansas Geological Society are: president, Harold O. Smedley, Skelly Oil Company; vice-president, Paul A. Harper, Cities Service Oil Company; secretary-treasurer, Francis E. Mettner, Transwestern Oil Company. The host society has appointed the following committees to arrange for the meeting.

General arrangements—Chairman, E. C. Moncrief, Fourth National Bank Building; Norman D. Clark, Virgil B. Cole, John W. Inkster.

Program—Chairman, Edward A. Koester, Orpheum Building; James I. Daniels, Jack W. Gardner, Delmer L. Powers.

Reception—Chairman, Millard W. Smith, Orpheum Building; Charles S. Agey, Lawrence C. Hay, L. C. Morgan, T. G. Wright.

Finance—Chairman, K. T. Woodman, Bitting Building; Melvern F. Bear, L. Leslie Cotter, Lee E. Phillips, Jr., Raymond A. Whortan.

Entertainment—Chairman, M. J. Boreing, Union National Bank Building; Lee H. Cornell, Jack H. Heathman, Robert B. McNeely, R. S. Webb.

Registration—Chairman, John L. Garlough, Fourth National Bank Building; Delbert J. Costa, Burton C. Dunn, Walter W. Larsh, Walter W. Heathman.

WEST TEXAS GEOLOGICAL SOCIETY FIELD TRIP, NOVEMBER 2 AND 3

The West Texas Geological Society will hold its annual Fall Field Trip on Saturday, November 2, and Sunday, November 3. The trip will be held in the region of the Glass Mountains with headquarters at the town of Marathon, with three-fourths of the trip covering the Permian rocks and one-fourth of the trip covering the pre-Permian rocks. Arrangements for reservations will be handled through the Society. Those interested in attending should contact Charles A. Shaw, Secretary of the West Texas Geological Society, Midland.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 10 (OCTOBER, 1946), PP. 1786-1788, 1 FIG.

MEMORIAL

OTTO DREHER

(1888–1945)

Otto Dreher was born on May 23, 1888, in Obertiefenbach in western Germany. He enrolled as a student at the University of Strassburg in 1906, attended the University of Marburg during 1907 and 1908, and obtained his Doctor of Philosophy degree from Strassburg in 1909 on his thesis work on the Rhön Mountains in Germany.

Early in 1912 Dr. Dreher entered the employ of the "Astra Romania" in Roumania, a subsidiary of the Royal Dutch-Shell Group. During World War I, he was a German officer in Roumania and France. After the war he became geological adviser of the Bataafsche Petroleum Company's head office at The Hague (Holland) and as such made various trips to Mexico (1923–1926) and the United States (1928–1929). In 1931 he moved to Hanover, where, until 1934, he took charge of the investigations carried out by the Royal Dutch-Shell Group in northwestern Germany. He afterward returned to The Hague in his former position.

During the last years of his life Dr. Dreher suffered from a creeping paralysis, the first symptoms of which appeared already in 1939. This disease gradually impaired his health and finally, on December 9, 1945, caused his death.

Dr. Dreher was an enthusiastic geologist, a keen observer, a conscientious worker, and a good organizer.

Owing to the war and to his nationality, Dr. Dreher, although not belonging to the National Socialistic party, lived the last years of his life lonely and almost forsaken by most of his former friends, at his home in Wassenaar near The Hague, nursed affectionately and with the greatest patience by his wife, who survived him with their two adult sons.

Dr. Dreher was a member of German and Netherlands geological societies, as well as of The American Association of Petroleum Geologists.

E. A. RITTER

BASLE, SWITZERLAND
August, 1946

DONALD DUDLEY HUGHES

(1893–1946)

Luck plays an important part in every man's life. It is seldom, however, that such combinations of misfortune occur to one man in so short a period. A scaffolding, from which Don was working on his new home, June 18, collapsed. The resulting fall, from no great height, shattered his left knee in a complex manner. He was taken to a hospital immediately and after a difficult operation recovered sufficiently to be taken home, July 5. On July 10, he developed symptoms of pneumonia and was returned to the hospital. From pneumonia he responded favorably, returning to his home in the morning of July 23 in cheery spirits. Four hours after his return he suffered a coronary embolism and passed away in a few minutes.

Donald Dudley Hughes was born in Humboldt, Nebraska, December 9, 1893. He attended primary school in Perry, Oklahoma; high school in Cripple Creek, Colorado. Work in the Cripple Creek mines inspired his interest in geologic science and led to his entrance at Kansas State Agricultural College in 1914. Before completion of his course, he

DONALD DUDLEY HUGHES

moved to Richmond, California, where he was employed in the Standard Oil Refinery during 1916 and 1917.

Don volunteered in the Army, April 23, 1917. He trained in aviation at San Diego and was commissioned as First Lieutenant, June, 13, 1918, in the Aviation Section, Signal Reserve Corps. He was shipped to France, where he served as Officer-in-Charge of the Aerial Gunnery School at St. Jean du Monts. Subsequent to the Armistice, Don was injured in a plane crash and was invalided to Ft. McPherson, Georgia. He was discharged from the Army, August 12, 1919. Returning to the University of Oklahoma, he secured his A.B. degree in 1921. From Oklahoma Don entered Stanford University where he was given his E.M. degree in 1923. In September of the same year, he started with the Marland Oil Company in the position of micropaleontologist. Upon the sale of the Marland, Don moved to The Texas Company and organized its micropaleontological department, serving until 1939, when he resigned to engage in consulting work. In 1942, Don was called to Stanford for a year as acting associate professor of geology. While with The Texas Company in 1934, he had become interested in the study of the Tertiary basin of Humboldt County. After leaving Stanford, he returned to Humboldt County where he was establishing his new home at the time of his untimely death.

It was while doing research work in the Cushman Laboratory for Foraminiferal Research that he met and subsequently married Miss Margaret Moore, Dr. Cushman's micropaleontological illustrator, July 8, 1935.

He was a member of the following scientific societies: American Association of Petroleum Geologists; Society of Economic Paleontologists and Mineralogists (president, 1944); Branner Club (president, 1933). He was also a member of the Sigma Nu Fraternity; Sigma Gamma Epsilon, and Alpha Zeta.

Numerous papers and collaborations with other workers on the microfaunal sections of California stratigraphy established Don Hughes as an authority on California micropaleontology, particularly the Humboldt Tertiary basin. His collection of microfaunal specimens, together with Mrs. Hughes' illustrations, is unique. His death terminates some much needed research in a neglected area of the Pacific Tertiary.

Don will be remembered by all who knew him for his kindness, courtesy, and unselfishness in helping others. He was a student, of wide interests and independent in thought. The profession generally and his friends in particular, can ill afford his passing.

ERIC K. CRAIG

FERNDALE, CALIFORNIA
August 16, 1946

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 10 (OCTOBER, 1946), PP. 1789-1796

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

Under the heading "Diving for Oil," the August, 1946, issue of *The Link*, house organ of the Carter Oil Company, describes and illustrates a 2-ton, airtight steel chamber which soon will be lowered from a control boat to the shallow ocean floor fringing the westward tips of the Bahama Island group, east of West Palm Beach, Florida. The 6-foot high, cylindrical diving "bell" will house one man and a gravity meter, and the Standard Oil Company (Bahamas) Limited, which is conducting this submarine, geophysical exploration for petroleum, estimates that about 50 readings per week may be obtained. Radar will be utilized in plotting the position of each reading.

WALTER S. MARTZ, JR., has left the Ashland Oil and Refining Company, and is associated with HEWLETT A. RUSSELL as consulting geologist, at Graham, Texas.

J. D. WEIR, recently with The California Standard Company, Calgary, is in the department of geology at the University of Saskatchewan, Saskatoon, Saskatchewan.

A. G. UNKLESBAY, recently with the Iowa Geological Survey, Iowa City, Iowa, may be addressed in care of the department of geology at Colgate University, Hamilton, New York.

JOSEPH MEADOWS DAWSON, consultant of Jackson, Mississippi, died on August 9, at the age of 50 years. Dawson joined the Association in 1923. For may years he was with the Gulf Production Company at San Antonio, Texas, and more recently he was engaged in consulting work.

BENJAMIN L PILCHER, JR., died on August 9, at an Albuquerque, New Mexico, hospital, at the age of 40 years, as the result of an automobile accident. His home was Midland, Texas, where he was with The Texas Company, for whom he had worked for many years.

MAX STEINEKE may be addressed in care of the Arabian American Oil Company, 200 Bush Street, San Francisco, California. He has been transferred from Saudi Arabia to domestic service.

The Fourth Field Trip of the Southeastern Geological Society was held September 27, 28, and 29, 1946, under the direction of F. STEARNS MACNEIL of the U. S. Geological Survey. The field-trip party examined Tertiary outcrops between the Chattahoochee and Conecuh rivers in southeastern Alabama. Copies of the Guidebook may be purchased, at $3.00, from the Society, Box 841, Tallahassee, Florida.

Bates and Cornell, consulting petroleum geologists and engineers, Lafayette, Louisiana, announce the addition to their organization of ROBERT R. COPELAND, JR., formerly geologist for The California Company at New Orleans.

F. B. PLUMMER, of the University of Texas Bureau of Economic Geology, is in Brazil making some investigations in the oil fields for the Brazilian Government.

H. I. TSCHOPP, general manager of the Shell Company of Ecuador Ltd., passed recently through New York en route to Quito, where he intends to stay until the beginning of next year. He will then return to Europe after more than 25 years of oil-geological experience in Latin-American countries.

The pre-Permian Study Group of the West Texas Geological Society has prepared a "Columnar Section of the Pre-Permian Rocks of the Central Basin Platform, West Texas, and Southeast New Mexico." The section contains a complete summarized description of all the pre-Permian rocks penetrated on the platform. This section can be obtained from the chairman of the publications committee, R. K. DEFORD, Argo Oil Corporation, Midland, Texas. The price is $1.00. Road logs of the Society's recent field trip to the Franklin and Hueco mountains are also obtianable. Included in the road logs is a complete stratigraphic section of the mountains and a geologic map of the area with the itinerary marked thereon. The price is $1.50.

ROLAND F. BEERS, president of The Geotechnical Corporation, and WILLIAM B. HEROY, former director of foreign production, Petroleum Administration for War, announce the formation of the firm of BEERS & HEROY, consulting geologists, geophysicists, and engineers to the petroleum and mineral industries, with offices in the Tower Petroleum Building, Dallas, Texas.

THOMAS A. HENDRICKS, U. S. Geological Survey staff geologist, has returned recently to Washington from General MacArthur's headquarters in Tokyo. As a scientific consultant assigned to GHQ-SCAP, he served for nearly a year as chief of the Mining and Geology Division, Natural Resources Section of that headquarters. He has now been placed in charge of a comprehensive survey of the geology of the continental shelf to be conducted by the Geological Survey, starting on a major scale in July, 1947, provided necessary funds are appropriated by Congress.

As reported in The Drift of Things, *Mining and Metallurgy* (August, 1946), p. 44c, under the caption Education of Engineers, 6,113 geologists were among the 396,865 scientific and professional men who were registered with The National Roster of Scientific and Specialized Personnel at the close of 1945. Compared with mining and metallurgical engineers, petroleum and natural gas engineers, as well as with civil, mechanical, chemical, and electrical engineers, the extent of education of the geologists is reported as being far greater, 24 per cent of those registered having an M.S. degree, and 17 per cent having a PH.D. degree.

FREDERICK A. GRASER, until recently consulting petroleum engineer of Long Beach, California, has accepted appointment as associate professor of petroleum engineering, Missouri School of Mines, Rolla, Missouri.

HOWARD C. PYLE, recently appointed vice-president in charge of oil-loan activities, Bank of America, Los Angeles, California, has been named as chairman of the Petroleum Division, A.I.M.E.

E. D. LYNTON, production division, Institut de Petrole, recently returned from France for the purpose of expediting shipment from the United States of both men and equipment needed in the current program of petroleum exploration sponsored by the French Government.

The recently reorganized Abilene Geological Society has elected the following officers: president, VINCENT C. PERINI, JR., Merry Brothers and Perini; vice-president, NORMAN D. FITZGERALD, independent; secretary-treasurer, J. C. HUNTER, JR.

BOUWE DYKSTRA, formerly with Asiatic Petroleum Corporation, is now associated with Shell Oil Company, Box 2099, Houston 1, Texas.

CLINTON A. LUETH, formerly of San Antonio, Texas, is now with United Gas and Pipe Line Company, Box 2492, Houston 1, Teaxs.

Following celebration of his 80th birthday on August 8, 1946, GEORGE H. ASHLEY retired as chief of the Pennsylvania Geological Survey. Serving for many years as geologist, and later as acting director of the U. S. Geological Survey, Ashley began his 27 years of service with the State of Pennsylvania when he accepted appointment in 1919, as State geologist. He organized the State Geological Survey, which has now completed the topographic mapping of 95 per cent of the area of Pennsylvania, in cooperation with the U. S. Geological Survey. The geologic map of Pennsylvania, on a scale of 1 inch equals 6 miles, and printed in 16 colors, was compiled under his direction and published in 1932. Ashley is the author of over 200 scientific and technical papers, and is president-elect of the Society of Economic Geologists. Assistant State geologist since 1922, RALPH W. STONE has been appointed to serve as chief geologist of the Pennsylvania Geological Survey until December 31, 1946, when he, too, will be retired.

Recently released from active military duty, CHESTER R. PELTO is now petrographer, War Department, Corps of Engineers, Omaha District, Omaha, Nebraska.

Formerly with the Union Producing Company, HARRY W. JOHNSTON, JR., is now employed by the Tennessee Gas and Transmission Company, Box 2511, Houston 1, Texas.

FREDERIC R. KELLEY is with the Tide Water Associated Oil Company, Box 1708, Casper, Wyoming.

JOHN H. MELVIN, formerly with the Pennsylvania Drilling Company of Pittsburgh, is now district geologist, U. S. Engineer Office, Omaha, Nebraska. He is engaged in the geological engineering phases of the Missouri River Development program.

W. E. BLACKMAN has resigned from the West Texas geological staff, Barnsdall Oil Company.

Friends of CHARLES BOHDANOWICZ will be interested in learning that he is now in Krakow, Poland, as director of the Geological Survey of Poland. He may be addressed in care of MICHAEL KONECKI, Grove Ferry, 11, Altar Drive, Heaton, Bradford, England.

I. K. NICHOLS, formerly with the Phillips Petroleum Company, is now working for The Texas Company, Box 2332, Houston, Texas.

Lieutenant RICHARD F. MILLER may be addressed: Hqtrs. 332nd Eng. Gen. Ser. Regt., APO 633, c/o P.M., N. Y., N. Y.

Lieutenant Colonel ALLEN C. TESTER, now on terminal leave from active duty with the Corps of Engineers, has resumed his duties as professor of geology at State University of Iowa, Iowa City.

WARREN D. SORRELS is now general manager of operations, Bennett and Sorrels, oil producers, 232 East Ohio Street, Chicago 11, Illinois.

PAUL W. NETTERSTROM has left the Shell Oil Company to join the staff of the Ohio Oil Company, Casper, Wyoming.

HOWARD A. GIBSON, formerly with Merry Brothers and Perini, Abilene, Texas, is now with Pan American Production Company, Mellie Esperson Building, Houston 2, Texas.

Released from active service with the Navy on May 9, 1946, GLENN E. MCKINLEY is now instructor in geology, Classen High School, Oklahoma City, Oklahoma.

Lieutenant Colonel JOSEPH D. TOMPKINS, independent oil operator of Texas, has been released from active duty with the Army Air Forces, and may be addressed at 1605 Gulf States Building, Dallas, Texas.

ROBERT W. EVERETT, JR., is with The Texas Company, Box 252, New Orleans, Louisiana. He was released from active service with the Army Air Forces on August 24, 1946.

ROSS L. HEATON has left The Texas Company to accept a position with the U. S. Bureau of Reclamation.

Released from active duty with the Navy, Lieutenant BEVERLY B. BRADISH is now a senior geologist for the Carter Oil Company, Lander, Wyoming.

FREDERICK M. SWAIN has resigned from the School of Mineral Industries, Pennsylvania State College, State College, Pennsylvania, to become assistant professor of geology in the department of geology at the University of Minnesota, St. Paul, Minnesota.

Major ROBERT M. BEATTY, formerly chief of the Library and Production Division, Natural Resources Section, GHQ-SCAP, Tokyo, is now with the Standard Oil Company (New Jersey), Apartado 1081, Lima, Peru.

Present overseas address of Sgt. CHARLES L. WILSON: 600th A.E.S., 7th A.S.G., APO 328, c/o PM San Francisco, California.

After 4 years of active duty with the Navy, including overseas participation in the B-29 mine-laying program, Commander GEOFFREY W. CRICKMAY has left the Navy to serve as a senior geologist for the Venezuelan Atlantic Refining Company, Apartado 893, Caracas, Venezuela.

Released from military service June 30, 1946, NORMAN W. EUBANK, JR., may now be addressed in care of the Eubank Equipment Company, Independence, Louisiana.

LAWRENCE C. CRAIG, formerly serving in General Headquarters, Tokyo, is now out of the Army and working for the U. S. Geological Survey, Washington, D. C.

Captain HARRY P. STOLZ, U.S.N.R., completed his tour of active duty with the Navy and is now back with the firm of Stanley and Stolz, consulting engineers and geologists, 510 South Spring Street, Los Angeles, California.

JOHN F. CAMP, JR., was released from active military service on August 10, 1946, and is now with John F. Camp and Sons, 1103 National Bank of Commerce Building, San Antonio 5, Texas.

Discharged from the Army May 14, 1946, ELVIN M. HURLBUT, JR., may now be addressed: Box 1038, El Campo, Texas.

JAMES LEE WILSON was released from the Army on August 21, 1946, and may be addressed in care of the Yale University Graduate School, New Haven, Connecticut.

PAUL H. FARMER has left the Gulf Refining Company, Mattoon, Illinois, to join the Brinkerhoff Drilling Company, Evansville, Indiana.

DONALD L. BLACKSTONE, JR., has left the Carter Oil Company to accept a teaching appointment at the University of Wyoming, Laramie.

MARK F. NERO is employed as an assistant field geologist by the Mene Grande oil Company, Caracas, Venezuela. After 2½ years of service in the U. S. Army Air Forces in the tropics of the Southwest Pacific, he was discharged, April 30, 1946, with the rank of Captain.

DART WANTLAND, formerly with Seismograph Service Corporation, now holds the position of geophysicist, U S. Reclamation Service, Denver, Colorado.

Colonel O. F. KOTICK may be addressed in care of the Army-Navy Petroleum Board, 2830 Navy Building, Washington 25, D. C. Prior to entering the service he was with the Tide Water Associated Oil Company, Oildale, California.

JOHN F. DURR, Belle Fourche, South Dakota, was released from active duty with the Navy, with the rank of ensign, on February 15, 1946.

Lieutenant Commander JOHN W. RUWWE was released from active duty with the Navy on August 5, 1946, and is now with the Phillips Petroleum Company, Box 791, Midland, Texas.

Now with the U. S. Bureau of Mines, 551 Federal Building, Dallas, Texas, Lieutenant Commander R. K. GUTHRIE was released from active duty with the Navy on July 9, 1946.

Formerly stationed with the U. S. Geological Survey at Eureka, Utah, T. S. LOVERING may now be addressed in care of the department of geology, University of Michigan, Ann Arbor, Michigan.

Released from active duty with the Navy in October, 1945, WILBURN H. SEALS is now employed by the Creole Production Corporation, Jesupin District, Caripito, Edo. Monagas, Venezuela.

HALL TAYLOR, after 3½ years overseas with the Army, has completed his terminal leave, and is now instructor in geology at Columbia University, New York City.

Lieutenant Colonel HUBERT G. SCHENCK, chief, Natural Resources Section, General Headquarters of the Supreme Commander for the Allied Powers in Tokyo, Japan, was recently elected a corresponding member of the Geological Society of Belgium.

CHALMER L. COOPER, formerly geologist with the Illinois State Geological Survey, has been appointed a senior geologist with the U. S. Geological Survey, Washington, D. C., where he is working in the office of the director, coordinating the activities of the various branches in the preparation of Survey reports for publication. Cooper has done similar work in the past for the Oklahoma, Kentucky, and Illinois geological surveys.

RAYMOND J. DILGER. formerly with the Trigood Oil Company, Casper, Wyoming, is now general manager of Fred M. Manning, Inc., 1004 Hamilton Building, Wichita Falls, Texas.

FREDERICK S. LILLIBRIDGE has left the Transwestern Oil Company to join the staff of the Sunray Oil Corporation, Midland, Texas.

GLENN G. BARTLE is now dean and professor of geology at the Triple Cities College of Syracuse University at Endicott, New York. He was formerly with E. Holley Poe and Associates, New York City.

EDWARD C. TABER, JR., has been released from the Army after 4 years of active duty, and is in the Houston office of Shell Oil Company.

Lieutenant Colonel WILLIAM M. NICHOLLS has been released from active duty with the Army Air Forces, and may be addressed: 134 West Craig Place, San Antonio 1, Texas.

W. C. RAY, independent operator of San Angelo, Texas, has been released from active duty with the Corps of Engineers, in which he held the rank of major. His address is 315 W. Twohig, San Angelo, Texas.

After serving in the 656th Engineer Topographic Battalion, RICHARD C. OBURN has received his Army discharge, and is now employed by the Atlantic Refining Company, His home address is Box 1672, Wichita 1, Kansas.

WILLIAM F. JENKS has given up his post as professor of geology at the Universidad Nacional de San Agustin, Arequipa, Peru, and has joined the faculty of the department of geology of the University of Rochester, Rochester, New York.

ARCHIE J. MACALPIN has resigned as engineering geologist, U. S. Bureau of Reclamation, Denver, Colorado, and has accepted appointment as an assistant professor in charge of geology, University of Notre Dame, Notre Dame, Indiana.

To encourage postgraduate scientific research, four graduates nominated by Canadian universities have been awarded Imperial Oil Ltd. fellowships, each of which may be held for three years at $1,000 yearly. Imperial is an affiliate of Standard Oil Company (New Jersey). These four fellowships will be granted annually in the future.

ROBERT E. ANDERSON was released from active duty with the Navy on June 28, and is now with the Signal Oil and Gas Company, Los Angeles, California.

KEITH M. HUSSEY has resigned from the faculty of the University of Houston to accept an appointment in the School of Geology, University of Oklahoma, Norman, Oklahoma.

Resigning from the department of paleontology, University of California, Berkeley, California, JOSEPH J. GRAHAM has joined the faculty of the department of geology at the Agricultural and Mechanical College of Texas, College Station, Texas.

RALPH L. BELKNAP was seriously injured this summer while teaching at the Geology Camp in Wyoming. He may be addressed in care of the department of geology, University of Michigan, Ann Arbor, Michigan.

H. B. FIELDS is now with the Carter Oil Company, Vernal, Utah. He was formerly with The Texas Company in Midland, Texas.

Formerly with the Shell Oil Company in Wichita, Kansas, JOHN R. BERG may now be addressed: Department of Geology, University of Wichita, Wichita, Kansas.

Upon his release from active duty with the Navy, JAMES B. CATHCART returned to the U. S. Geological Survey and is stationed in Carlsbad, New Mexico.

JACK L. HOUGH is now with the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

WALTER H. HEGWEIN, formerly with the Caribbean Petroleum Company, Maracaibo, Venezuela, S. A., is now with the Allied Control Commission, British Military Mission, Roumania, C. M. F.

ROBERT T. BENNETT is employed as a geologist by The Texas Company, Box 252, New Orleans, Louisiana. He was formerly with the National Associated Petroleum Company, Tulsa, Oklahoma.

W. R. HOGAN, JR., has left the Shell Oil Company and is now with Erle P. Halliburton, Inc., Duncan, Oklahoma.

Formerly stationed in Miami, Florida, as chief geologist of the Republic Oil Company, RAY V. HENNEN may now be addressed: c/o M. L. Benedum, 311 First National Bank Building, Shreveport 23, Louisiana.

Separated from the Navy on May 10, PAUL SIEMON is now employed in Casper, Wyoming, by the Tide Water Associated Oil Company.

WILLIAM RAMSAY GRAY, formerly with Geophysical Service, Inc., Dallas, Texas, is now employed by the Sun Oil Company, 1369 Zang Boulevard, Dallas 8, Texas.

Major ROBERT W. BLAIR, 3983 Haddon Road, Denver 5, Colorado, completed active duty with the Army Air Forces on October 14.

GLEN LEE CORRIGAN is an associate professor of mechanical engineering at Oklahoma A. and M. College, Stillwater, Oklahoma.

Formerly in Managua, Nicaragua, with the American International Fuel and Petroleum Company, C. W. FLAGLER is now with the Danish American Prospecting Company, Gammeltorv, 6, Copenhagen, Denmark.

JOHN PAUL GRIES has left the Magnolia Petroleum Company to accept an appointment in the department of geology, State School of Mines, Rapid City, South Dakota.

ROBERT C. LAFFERTY is opening a consulting geological office in Charleston, West Virginia. He was formerly with the Owens, Libby-Owens Gas Department.

JOHN RODGERS has resigned from the U. S. Geological Survey to join the department of geology at Yale University, New Haven, Connecticut. He will teach courses on the geology of sedimentary rocks.

CYRIL B. TAYLOR, consulting geologist, has moved from Abilene to Dallas, Texas, where his address is: 4352 San Carlos Drive.

ROGER L. MESSMAN has moved from Hays, Kansas, to Ponca City, Oklahoma, where he is employed in the geological department of the Continental Oil Company.

Following his release from military service, LOUIS J. WILBERT, JR., has been instructing in the School of Geology, Louisiana State University, Baton Rouge, Louisiana.

Released from military service, July 14, RICHARD F. CAST is employed by the Phillips Petroleum Company, Box 1926, San Benito, Texas.

D. R. KNOWLTON is now a reservoir engineer with the Kettleman North Dome Association, Avenal, California. He was formerly with the California Conservation Committee, San Gabriel, California.

M. L. THOMPSON has joined the faculty of the department of geology at the University of Wisconsin, Madison, Wisconsin. He was formerly with the department of geology at the University of Kansas, Lawrence, Kansas.

Commander CLARENCE W. HOFFER was released to inactive duty in the Naval Reserve, July 11, 1946, and has returned to his consulting geological office at 532 20th Street, N.W., Washington 6, D. C. He was chief of the Metals and Minerals Division, O. P. & M., Navy Department, Washington, D. C., and executive officer of the U. S. Naval Station at Coco Solo, Canal Zone.

EDMOND G. OTTON was released from the Army on August 31 and is now with the U. S. Geological Survey, Washington, D. C.

Captain ARTHUR J. MESTIER, JR., CAC(AA), was released from active military duty on September 1 and is employed by the Allis-Chalmers Manufacturing Company, West Allis, Wisconsin.

The new address of GLADYS PEYSER is: Box 1956, University, Alabama.

Following his release from the service, M. CHURCHILL HAENKE has entered private business and may be addressed: 246 East Forest Avenue, Arcadia, California.

RUSSELL M. JEFFORDS has resigned from the Kansas Geological Survey to accept an appointment in the department of geology at Brown University, Providence, Rhode Island.

Resigning from the department of geology, Northwestern University, Evanston, Illinois, JOHN R. BALL has joined the department of geology and geography at Kansas City University, Kansas City, Missouri.

WALLACE W. WILSON has resigned from the Ryder-Scott Company, Bradford, Pennsylvania, and is employed as an assistant research engineer by the California Research Corporation (Standard Oil Company of California subsidiary), Whittier, California.

CARLTON H. BEAL, consulting geologist of Los Angeles, California, died on September 7 at the age of 57.

LAWRENCE W. HEWITT, geologist for Socony-Vacuum Oil Company, Inc., died in New York, N. Y., on September 5.

GLENN S. DILLE has resigned as vice-president in charge of land and exploration for Deep Rock Oil Corporation and is reentering the field of consulting geology.

At a recent meeting of the Pittsburgh Geological Society, HUGH R. BRANKSTONE, Gulf Oil Corporation, was elected president for the year 1946–1947. Other officers include SHAILER S. PHILBRICK, vice-president; W. B. ROBINSON, secretary, and C. H. FELDMILLER, treasurer. Councillors for the year will be GEO. C. GROW, JR., past-president, RAYMOND E. BIRCH, DANIEL A. BUSCH, RICHARD M. FOOSE JOHN T. GALEY, J. LEROY KAY, and JAMES H. C. MARTENS. During the past year the society held nine regular meetings, at which a wide range of subject matter was discussed. The society's membership has reached 190 and is composed of diverse geologic interests, such as oil and gas, ceramics, steel, coal, and academic.

N. RAYMOND LAMB, New Mexico Bureau of Mines and Minerals, has been appointed a member of the engineering committee of the Interstate Oil Compact Commission.

The New Mexico Bureau of Mines and Mineral Resources sponsored a geological field trip to the San Juan basin on September 20–22.

MAX B. PAYNE, formerly with the Richfield Oil Corporation, is now employed by the Union Oil Company of California, Crites Building, Bakersfield, California.

ROSS M. PHILLIPS has opened a geological office in Bakersfield, California, for the British-American Oil Producing Company. He was formerly with The Texas Company in Fellows, California.

A. H. WADSWORTH, JR., has left the U. S. Geological Survey to accept a position as exploration geologist in New Mexico for the American Smelting and Refining Company.

Released from military service September 9, HAROLD W. ADDINGTON is working for the California Company in Rangely, Colorado.

CHARLES A. RENFROE is an instructor in the geology department of the University of Oklahoma, Norman, Oklahoma. He was formerly employed by the Superior Oil Company.

PROFESSIONAL DIRECTORY

ALABAMA

HARRY R. HOSTETTER
Core Drilling Contractor
Specialist in Reverse Circulation Coring
100% Recovery
Monroeville, Alabama
P.O. Box 388 Tel. 39-W

CALIFORNIA

J. L. CHASE
Geologist — *Geophysicist*
169 LaVerne Avenue
LONG BEACH 3 CALIFORNIA
Tel. 816-04
Specializing in Magnetic Surveys

VERNON L. KING
Petroleum Geologist and Engineer
707 South Hill Street
Los Angeles, California
Vandike 7087

JEROME J. O'BRIEN
Petroleum Geologist
Examinations, Reports, Appraisals
Petroleum Building
714 West Olympic Boulevard
McLarthy & O'Brien Los Angeles 15, Calif.

HENRY SALVATORI
Western Geophysical Company
711 Edison Building
601 West Fifth Street
LOS ANGELES, CALIFORNIA

COLORADO

C. A. HEILAND
Heiland Research Corporation
130 East Fifth Avenue
DENVER 9, COLORADO

EVERETT S. SHAW
Geologist and Engineer
3131 Zenobia Street
DENVER COLORADO

CALIFORNIA

H. W. BELL
Geologist and Engineer
Consultant in Oil, Gas, Mining
for
Development, Production, Appraisal
1136 Wild Rose Dr., Santa Rosa, Calif.

PAUL P. GOUDKOFF
Geologist
Geologic Correlation by Foraminifera
and Mineral Grains
799 Subway Terminal Building
LOS ANGELES, CALIFORNIA

A. I. LEVORSEN
Petroleum Geologist
Stanford University California

ERNEST K. PARKS
Consultant in
Petroleum and Natural Gas Development
and
Engineering Management
614 S. Hope St.
LOS ANGELES, CALIFORNIA

RICHARD L. TRIPLETT
Core Drilling Contractor
PArkway 9925 1660 Virginia Road
Los Angeles 6, Calif.

COLORADO

HARRY W. OBORNE
Geologist
304 Mining Exchange Bldg. 230 Park Ave.
Colorado Springs, Colo. New York, N.Y.
Main 5663 Murray Hill 9-3541

L. BRUNDALL A. R. WASEM
Geophoto Services, Inc.
Photogeologists and Consulting Geologists
Mountain States Exploration Drilling Co.
Core Drilling
110 W. 13th Ave. DENVER, COLO.

ILLINOIS

C. E. BREHM AND J. L. McMANAMY
Consulting Geologists and Geophysicists
New Stumpp Building, Mt. Vernon, Illinois

L. A. MYLIUS
Geologist Engineer
122A North Locust Street
Box 264, Centralia, Illinois

T. E. WALL
Geologist
Mt. Vernon Illinois

INDIANA

HARRY H. NOWLAN
Consulting Geologist and Engineer
Specializing in Valuations
Evansville 19, Indiana
317 Court Bldg. Phone 2-7818

KANSAS

WENDELL S. JOHNS
PETROLEUM
GEOLOGIST
Office Phone 3-1540 600 Bitting Building
Res. Phone 2-7266 Wichita 2, Kansas

C. ENGSTRAND
Detailed Lithologic Logs
KANSAS SAMPLE LOG SERVICE
415 N. Pershing
Wichita Kansas

LOUISIANA

WILLIAM M. BARRET, INC.
Consulting Geophysicists
Specializing in Magnetic Surveys
Giddens-Lane Building SHREVEPORT, LA.

CYRIL K. MORESI
Consulting Geologist
Jeanerette, Louisiana
Box 126 Phone 59
Phone 484-W

MISSISSIPPI

R. Merrill Harris Willard M. Payne
HARRIS & PAYNE
Geologists
100 East Pearl Bldg. Phone 4-6286
Jackson, Miss. or L.D. 89

G. JEFFREYS
Geologist *Engineer*
Specialist, Mississippi & Alabama
100 East Pearl Street
Box 2415 Depot P.O.
Jackson, Mississippi

MELLEN & MONSOUR
Consulting Geologists
Frederic F. Mellen E. T. "Mike" Monsour
Box 2571, West Jackson, Mississippi
112½ E. Capitol St. Phone 2-1368

E. P. THOMAS
Geologist
Contract Surface Geology
967 N. Congress St. Phones Day 3-7401 Night 4-6327
Jackson, Miss.

NEW YORK

BROKAW, DIXON & McKEE
Geologists *Engineers*
OIL—NATURAL GAS
Examinations, Reports, Appraisals
Estimates of Reserves
120 Broadway Gulf Building
New York Houston

FRANK RIEBER
Geophysicist
Specializing in the development of new instruments and procedures
127 East 73d St. New York 21

NORTH CAROLINA

RODERICK A. STAMEY
Petroleum Geologist
109 East Gordon Street
KINSTON NORTH CAROLINA

OHIO

JOHN L. RICH
Geologist
General Petroleum Geology
Geological Interpretation of Aerial Photographs
University of Cincinnati
Cincinnati, Ohio

OKLAHOMA

ELFRED BECK
Geologist
308 Tulsa Loan Bldg. Box 55
TULSA, OKLA. DALLAS, TEX.

WARREN L. CALVERT
President
The American Exploration Service, Inc.
Core and Stratigraphic Drilling
Elevation and Geologic Service
811 Tradesmens Bank Bldg., Oklahoma City, Okla.

CRAIG FERRIS
Geophysicist
E. V. McCollum & Co.
1510 Thompson Bldg.
Tulsa 3, Okla.

WALTER E. HOPPER
Geologist and Consultant
Petroleum and Natural Gas
Reports Appraisals
Estimates of Reserves
510 National Mutual Building Tulsa 3, Oklahoma

R. W. LAUGHLIN
WELL ELEVATIONS
LAUGHLIN-SIMMONS & CO.
615 Oklahoma Building
TULSA OKLAHOMA

FRANK A. MELTON
Consulting Geologist
Aerial Photographs
and Their Structural Interpretation
1010 Chautauqua Norman, Oklahoma

CLARK MILLISON
Petroleum Geologist
Philtower Building
TULSA OKLAHOMA

P. B. NICHOLS
Mechanical Well Logging
THE GEOLOGRAPH COMPANY
25 Northwestern
Oklahoma City Oklahoma

JOSEPH A. SHARPE
Geophysicist
C. H. PROST GRAVIMETRIC SURVEYS, INC.
1242 South Boston Ave. Tulsa 3, Okla.

C. L. WAGNER
Consulting Geologist
Petroleum Engineering
Geophysical Surveys
2259 South Troost St.
TULSA OKLAHOMA

WARE & KAPNER
SAMPLE LOG SERVICE
Wildcat Sample Log Service
Covering Southern Oklahoma
John M. Ware H. H. Kapner
Tulsa, Oklahoma
2514 South Norfolk 4-2539

G. H. WESTBY
Geologist and Geophysicist
Seismograph Service Corporation
Kennedy Building Tulsa, Oklahoma

PENNSYLVANIA

HUNTLEY & HUNTLEY
Petroleum Geologists and Engineers
Grant Building, Pittsburgh, Pa.
L. G. Huntley
J. R. Wylie, Jr.
James F. Swain

TEXAS

JOSEPH L. ADLER
Geologist and Geophysicist
Contracting Geophysical Surveys in Latin America
Independent Exploration Company
Esperson Building Houston, Texas

HART BROWN
Brown Geophysical Company
Gravity
P.O. Box 6005 Houston 6, Texas

PAUL CHARRIN
Geologist and Geophysicist
Universal Exploration Company
2044 Richmond Road, Houston 6, Texas
913 Union National Bank Building
Houston 2, Texas

CUMMINS, BERGER & PISHNY
Consulting Engineers & Geologists
Specializing in Valuations
1603 Commercial Standard Bldg.
Fort Worth 2, Texas
Ralph H. Cummins
Walter R. Berger
Chas. H. Pishny

E. DeGOLYER
Geologist
Esperson Building
Houston, Texas
Continental Building
Dallas, Texas

ALEXANDER DEUSSEN
Consulting Geologist
Specialist, Gulf Coast Salt Domes
1006 Shell Building
HOUSTON, TEXAS

CHESTER F. BARNES
Geologist and Geophysicist
Petroleum Bldg. P.O. Box 266, Big Spring, Tex.

D'ARCY M. CASHIN
Geologist *Engineer*
Specialist Gulf Coast Salt Domes
Examinations, Reports, Appraisals
Estimates of Reserves
705 Nat'l Standard Bldg.
HOUSTON, TEXAS

LEAVITT CORNING, JR.
Consulting Geologist
Specializing in Magnetometer Surveys and Geological Interpretation of Results
Milam Building San Antonio, Texas

R. H. DANA
Southern Geophysical Company
Sinclair Building
FORT WORTH, TEXAS

DAVID DONOGHUE
Consulting Geologist
Appraisals - Evidence - Statistics
Fort Worth National Bank Building
FORT WORTH, TEXAS

TEXAS

J. E. (BRICK) ELLIOTT

Petroleum Geologist

108 West 15th Street Austin, Texas

JAMES F. GIBBS

Consulting Geologist and Petroleum Engineer

505 City National Bank Building

WICHITA FALLS, TEXAS

CECIL HAGEN

Geologist

Gulf Bldg. HOUSTON, TEXAS

SIDON HARRIS

Southern Geophysical Company

1003 Sinclair Building, FORT WORTH 2, TEXAS

JOHN M. HILLS

Consulting Geologist

Midland, Texas

Box 418 Phone 1015

R. V. HOLLINGSWORTH
HAROLD L. WILLIAMS

PALEONTOLOGICAL LABORATORY

Box 51 Phone 2359

MIDLAND, TEXAS

C. E. HYDE

Geologist and Oil Producer

1715 W. T. Waggoner Building

FORT WORTH 2, TEXAS

R. H. FASH

Vice-President

THE FORT WORTH LABORATORIES

Analyses of Brines, Gas, Minerals, Oil, Interpretation of Water Analyses. Field Gas Testing.

828½ Monroe Street FORT WORTH, TEXAS

Long Distance 138

JOHN A. GILLIN

National Geophysical Company

Tower Petroleum Building

Dallas, Texas

MICHEL T. HALBOUTY

Consulting Geologist and Petroleum Engineer

Suite 729-32, Shell Bldg.

Houston 2, Texas Phone P-6376

L. B. HERRING

Geologist

Natural Gas Petroleum

Second National Bank of Houston, Houston, Texas

SAMUEL HOLLIDAY

Consulting Paleontologist

Houston, Texas

Box 1957, Rt. 17 M. 2-1134

J. S. HUDNALL G. W. PIRTLE

HUDNALL & PIRTLE

Petroleum Geologists

Appraisals Reports

Peoples Nat'l. Bank Bldg. TYLER, TEXAS

JOHN S. IVY

Geologist

1124 Niels Esperson Bldg., HOUSTON, TEXAS

TEXAS

W. P. JENNY
Consulting Geologist and Geophysicist
Specializing in MICROMAGNETIC SURVEYS, GEOLOGICAL INTERPRETATIONS and CORRELATIONS of seismic, gravimetric, electric and magnetic surveys.
1404 Esperson Bldg. HOUSTON, TEXAS

JOHN D. MARR
Geologist and Geophysicist
SEISMIC EXPLORATION, INC.
Gulf Building Houston, Texas

GEORGE D. MITCHELL, JR.
Geologist and Geophysicist
ADVANCED EXPLORATION COMPANY
622 First Nat'l. Bank Bldg. Houston 2, Texas

LEONARD J. NEUMAN
Geology and Geophysics
Contractor and Counselor
Reflection and Refraction Surveys
943 Mellie Esperson Bldg. Houston, Texas

DABNEY E. PETTY
10 Tenth Street
SAN ANTONIO, TEXAS
No Commercial Work Undertaken

ROBERT H. RAY
ROBERT H. RAY, INC.
Geophysical Engineering
Gravity Surveys and Interpretations
Natl. Std. Bldg. Houston 2, Texas

JAMES L. SAULS, JR.
Geophysicist
ADVANCED EXPLORATION COMPANY
622 First Nat'l. Bank Bldg. Houston 2, Texas

H. KLAUS
MID-CONTINENT TORSION BALANCE SURVEYS
SEISMIC AND GRAVITY INTERPRETATIONS
KLAUS EXPLORATION COMPANY
Geologist and Geophysicist
115 South Jackson, Enid, Oklahoma
2223 15th Street, Lubbock, Texas

HAYDON W. McDONNOLD
Geologist and Geophysicist
KEYSTONE EXPLORATION COMPANY
2813 Westheimer Road Houston, Texas

R. B. MITCHELL
Consulting Geologist
Petroleum and Natural Gas
Second National Bank Building
Houston 2, Texas Capitol 7319

E. JOE SHIMEK HART BROWN
GEOPHYSICAL ASSOCIATES
Seismic
P.O. Box 6005 Houston 6, Texas

J. C. POLLARD
Robert H. Ray, Inc.
Rogers-Ray, Inc.
Geophysical Engineering
National Standard Bldg. Houston 2, Texas

F. F. REYNOLDS
Geophysicist
SEISMIC EXPLORATIONS, INC.
Natl. Std. Bldg. Houston 2, Texas

HUGH C. SCHAEFFER
Geologist and Geophysicist
NORTH AMERICAN
GEOPHYSICAL COMPANY
636 Bankers Mortgage Bldg. Houston 2, Texas

PROFESSIONAL DIRECTORY

TEXAS

SIDNEY SCHAFER
Consulting Geophysicist
Seismic Reviews Interpretations
Exploration Problems
3775 Harper St. Houston 5, Texas

Henry F. Schweer Geo. P. Hardison
SCHWEER AND HARDISON
Independent Consulting Petroleum Geologists
426-28 Waggoner Building
Wichita Falls, Texas
Specialists: Air-Surface Reconnaissance

A. L. SELIG
Consulting Geologist
Gulf Building Houston, Texas

WM. H. SPICE, JR.
Consulting Geologist
2101-02 Alamo National Building
SAN ANTONIO, TEXAS

HARRY C. SPOOR, JR.
Consulting Geologist
Petroleum . . . . . Natural Gas
Commerce Building Houston, Texas

CHARLES C. ZIMMERMAN
Geologist and Geophysicist
KEYSTONE EXPLORATION COMPANY
2813 Westheimer Road Houston, Texas

WEST VIRGINIA

DAVID B. REGER
Consulting Geologist
217 High Street
MORGANTOWN WEST VIRGINIA

WYOMING

E. W. KRAMPERT
Geologist
P.O. Box 1106
CASPER, WYOMING

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

COLORADO

ROCKY MOUNTAIN
ASSOCIATION OF PETROLEUM
GEOLOGISTS
DENVER, COLORADO
President - - - - - - - J. W. Vanderwilt
Mining Geologist
Midland Savings Building
1st Vice-President - - - - - C. A. Heiland
Heiland Research Corporation
2nd Vice-President - - - - Robert McMillan
Geophoto Services, Inc.
136 East Twentieth Ave.
Secretary-Treasurer - - - - - A. W. Cullen
1024 Continental Oil Building
Luncheons every Friday noon, Cosmopolitan Hotel. Evening dinner (6:15) and program (7:30) first Monday each month or by announcement, Cosmopolitan Hotel.

FLORIDA

SOUTHEASTERN
GEOLOGICAL SOCIETY
Box 841
TALLAHASSEE, FLORIDA
President - - - - - - - - - - I. J. Reed
The California Company
Vice-President - - - - - - - Walter B. Jones
Geological Survey of Alabama
Secretary-Treasurer - - - - - - H. A. Sellin
Magnolia Petroleum Company
Meetings will be announced. Visiting geologists and friends are welcome.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - - - - Jack Hirsch

Vice-President - - - - - - - - E. E. Rehn
Sohio Petroleum Company
Box 537, Mt. Vernon

Secretary-Treasurer - - - - John B. Patton
Magnolia Petroleum Company
Box 535, Mt. Vernon

Meetings will be announced.

INDIANA-KENTUCKY

INDIANA-KENTUCKY GEOLOGICAL SOCIETY
EVANSVILLE, INDIANA

President - - - - - - - - Charles W. Honess
Gulf Refining Company, Box 774

Vice-President - - - - - - - J. Albert Brown
Sohio Petroleum Co.
Owensboro, Kentucky

Secretary-Treasurer - - - - - F. H. Latimer
Sun Oil Company
Evansville, Ind.

Meetings will be announced.

KANSAS

KANSAS GEOLOGICAL SOCIETY
WICHITA, KANSAS

President - - - - - - Harold O. Smedley
Skelly Oil Company

Vice-President - - - - - - - Paul A. Harper
Cities Service Oil Company

Secretary-Treasurer - - - Francis E. Mettner
Transwestern Oil Company
603 Union National Bank Building

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. The Society sponsors the Kansas Well Log Bureau, 412 Union National Bank Building, and the Kansas Well Sample Bureau, 137 North Topeka.

LOUISIANA

NEW ORLEANS GEOLOGICAL SOCIETY
NEW ORLEANS, LOUISIANA

President - - - - - - - R. R. Copeland, Jr.
The California Company, 1818 Canal Bldg.

Vice-President and Program Chairman - - - - - - - - - - - - Richard L. Denham
Humble Oil and Refining Company

Secretary-Treasurer - - - - - Philip R. Allin
Gulf Refining Company, Harvey, La.

Meets the first Monday of every month, October-May inclusive, 7:30 P.M., St. Charles Hotel. Special meetings by announcement. Visiting geologists cordially invited.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY
SHREVEPORT, LOUISIANA

President - - - - - - - - - T. H. Philpott
Carter Oil Company

Vice-President - - - - - - - Brame Womack
Sohio Petroleum Corporation

Secretary-Treasurer - - - - - - - J. Ed. Lytle
Union Producing Company

Meets monthly, September to May, inclusive, in the State Exhibit Building, Fair Grounds. All meetings by announcement.

LOUISIANA

SOUTH LOUISIANA GEOLOGICAL SOCIETY
LAKE CHARLES, LOUISIANA

President - - - - - - - - - - J. A. Moore
Union Sulphur Company

Vice-President - - - - - - - James M. Bugbee
Shell Oil Company, Inc.

Secretary - - - - - - - - - Lloyd D. Traupe
Ohio Oil Company

Treasurer - - - - - - - - - D. E. Newland
Magnolia Petroleum Company

Meetings: Dinner and business meetings third Tuesday of each month at 7:00 P.M. at the Majestic Hotel. Special meetings by announcement. Visiting geologists are welcome.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - - - Rex P. Grant
Michigan Geological Survey
Capitol Savings and Loan Bldg., Lansing

Vice-President - - - - - Richard H. Wolcott
Sohio Petroleum Company, Mt. Pleasant

Secretary-Treasurer - - - - Charles K. Clark
Pure Oil Company
402 2d Natl. Bank Bldg., Saginaw

Business Manager - - - Kenneth A. Gravelle
Gulf Refining Company, Box 811, Saginaw

Meetings: Bi-monthly from November to April at Lansing. Afternoon session at 3:00, informal dinner at 6:30 followed by discussions. (Dual meetings for the duration.) Visiting geologists are welcome.

MISSISSIPPI

MISSISSIPPI GEOLOGICAL SOCIETY
JACKSON, MISSISSIPPI

President - - - - - - - - Frederic F. Mellen
Mellen & Monsour
Box 2571, W. Jackson Sta.

Vice-President - - - - - - - - J. B. Wheeler
Stanolind Oil and Gas Company

Secretary-Treasurer - - - - - - H. L. Spyres
Skelly Oil Company

Meetings: First and third Thursdays of each month, from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

OKLAHOMA

ARDMORE GEOLOGICAL SOCIETY
ARDMORE, OKLAHOMA

President - - - - - - - - F. P. Schweers
The Texas Company, Box 539

Vice-President - - - - - Paul L. Bartram
Phillips Petroleum Company

Secretary-Treasurer - - - - - - Ben S. Curtis
Independent, Box 156

Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

President - - - - - - - - Gerald C. Maddox
Carter Oil Company

Vice-President - - - - - - Harold J. Kleen
Skelly Oil Company

Secretary-Treasurer - - - - Frederick H. Kate
Shell Oil Company, Inc.
965 First National Building

Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every second and fourth Thursday of each month, at 12:00 noon, Y.W.C.A.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - - - - Delbert F. Smith
Oklahoma Seismograph Company

Vice-President - - - - - - Henry A. Campo
Atlantic Refining Company

Secretary-Treasurer - - - - Marcelle Mousley
Atlantic Refining Company, Box 169

Meets the fourth Thursday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

TULSA GEOLOGICAL SOCIETY
TULSA, OKLAHOMA

President - - - - - - - - John G. Bartram
Box 591, Stanolind Oil and Gas Co.

1st Vice-President - - - - - Russell S. Tarr
Independent, Beacon Building

2nd Vice-President - - - - - John C. Maher
U. S. Geological Survey

Secretary-Treasurer - - - - - John R. Crain
Ashland Oil and Refining Company

Editor - - - - - - - - Robert F. Walters
Box 661, Gulf Oil Corporation

Meetings: First and third Mondays, each month, from October to May, inclusive at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Friday (October-May), Chamber of Commerce Building.

TEXAS

CORPUS CHRISTI GEOLOGICAL SOCIETY
CORPUS CHRISTI, TEXAS

President - - - - - - - - W. E. Greenman
The Texas Company, 902 Jones Building

Vice-President - - - - - - Dale L. Benson
Sinclair Prairie Oil Company, Box 480

Secretary-Treasurer - - - - - O. G. McClain
Consultant, 224 Nixon Building

Regular luncheons, every Wednesday, Petroleum Room, Plaza Hotel, 12:05 P.M. Special night meetings, by announcement.

DALLAS GEOLOGICAL SOCIETY
DALLAS, TEXAS

President - - - - - - - - John W. Clark
Magnolia Petroleum Company, Box 900

Vice-President - - - - - - Willis G. Meyer
DeGolyer and MacNaughton, Continental Building

Secretary-Treasurer - - - - John M. Clayton
Seaboard Oil Company, 1400 Continental Building

Executive Committee - - - - Fred H. Wilcox
Magnolia Petroleum Company

Meetings: Monthly luncheons by announcement. Special night meetings by announcement.

EAST TEXAS GEOLOGICAL SOCIETY
TYLER, TEXAS

President - - - - - - - - T. H. Shelby, Jr.
Humble Oil and Refining Company

Vice-President - - - - - - George N. Ely
Continental Oil Company
907 Peoples Bank Building

Secretary-Treasurer - - - - - B. F. Murphy
Amerada Petroleum Corporation
Box 2026

Luncheons: Each week, Monday noon, Blackstone Hotel.

Evening meetings and programs will be announced. Visiting geologists and friends are welcome.

FORT WORTH GEOLOGICAL SOCIETY
FORT WORTH, TEXAS

President - - - - - - - - John H. Wilson
Independent Exploration Company
2210 Ft. Worth National Bank Bldg.

Vice-President - - - - - - Edwin M. Rowser
The Texas Company, Box 1720

Secretary-Treasurer - - S. K. Van Steenbergh
Sinclair Prairie Oil Company
901 Fair Building

Meetings: Luncheon at noon, Hotel Texas, first and third Mondays of each month. Visiting geologists and friends are invited and welcome at all meetings.

HOUSTON GEOLOGICAL SOCIETY

HOUSTON, TEXAS

President - - - - - - - - Shapleigh G. Gray
Consultant, 1713 Esperson Building

Vice-President - - - - - Charles H. Sample
J. M. Huber Corporation
721 Bankers Mortgage Bldg.

Secretary - - - - - - - - - A. F. Childers
Gulf Oil Corporation, Box 2100

Treasurer - - - - - - - - Wayne Z. Burkhead
Union Oil Company of California
1134 Commercial Bldg.

Regular meeting held the second and fourth Mondays at noon (12 o'clock), Mezzanine floor, Rice Hotel. For any particulars pertaining to the meetings write or call the secretary.

NORTH TEXAS GEOLOGICAL SOCIETY

WICHITA FALLS, TEXAS

President - - - - - - - - Dolph S. Simic
Cities Service Oil Company

Vice-President - - - - - - Lynn L. Harden
Sinclair Prairie Oil Company

Secretary-Treasurer - - - - - - Turner Wynn
Stanolind Oil and Gas Company

Luncheons and evening programs will be announced.

SOUTH TEXAS GEOLOGICAL SOCIETY

SAN ANTONIO, TEXAS

President - - - - - - - - - Thornton Davis
Peerless Oil and Gas Company
2023 Alamo National Building

Vice-President - - - - - - Marion J. Moore
Transwestern Oil Company, 1600 Milam Building

Secretary-Treasurer - - - - - Paul B. Hinyard
Shell Oil Company, Inc.
2000 Alamo National Building

Meetings: One regular meeting each month in San Antonio. Luncheon every Monday noon at Milam Cafeteria, San Antonio.

WEST TEXAS GEOLOGICAL SOCIETY

MIDLAND, TEXAS

President - - - - - - - - - B. A. Ray
Consulting, Box 1385

Vice-President - - - - - - W. J. Hilseweck
Gulf Oil Corporation, Box 1150

Secretary-Treasurer - - - - Charles A. Shaw
Forest Oil Corporation, Box 366

Meetings will be announced.

WEST VIRGINIA

THE APPALACHIAN GEOLOGICAL SOCIETY

CHARLESTON, WEST VIRGINIA
P. O. Box 2605

President - - - - - - - - Veleair C. Smith
1901 Kanawha Valley Building

Vice-President - - - - - - W. B. Maxwell
United Fuel Gas Company, Box 1273

Secretary-Treasurer - - - - - R. L. Alkire
605 Union Building

Editor - - - - - - - - - - J. D. Castner
Box 1433

Meetings Second Monday, each month, except June July, and August, at 6:30 P.M., Kanawha Hotel.

THE SOCIETY OF EXPLORATION GEOPHYSICISTS

President - - - - - - - - - J. J. Jakosky
University of Southern California, Los Angeles

Vice-President - - - - - - Cecil H. Green
Geophysical Service, Inc., 1311 Republic Bank Building, Dallas, Texas

Editor - - - - - - - - - - L. L. Nettleton
Gravity Meter Exploration Co.
1348 Esperson Bldg., Houston, Tex.

Secretary-Treasurer - - - George E. Wagoner
Carter Oil Company, Shreveport, Louisiana

Past-President - - - - - - Henry C. Cortes
Magnolia Petroleum Co., Dallas, Texas

Business Manager - - - - Colin C. Campbell
213 Ritz Building, Tulsa, Oklahoma
P.O. Box 1614

WYOMING

WYOMING GEOLOGICAL ASSOCIATION

CASPER, WYOMING
P. O. Box 545

President - - - - - - - - William H. Curry
Atlantic Refining Company

1st Vice-President - - - - - Robert L. Sielaff
Sinclair-Wyoming Oil Company

2nd Vice-President (Programs) - P. W. Reinhart
Shell Oil Company, Inc.

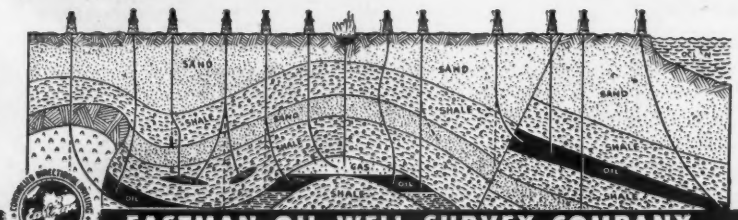
Secretary-Treasurer - - - David T. Hoenshell
General Petroleum Corporation

Informal luncheon meetings every Friday, 12 noon, Townsend Hotel. Visiting geologists welcome. Special Meetings by announcement.

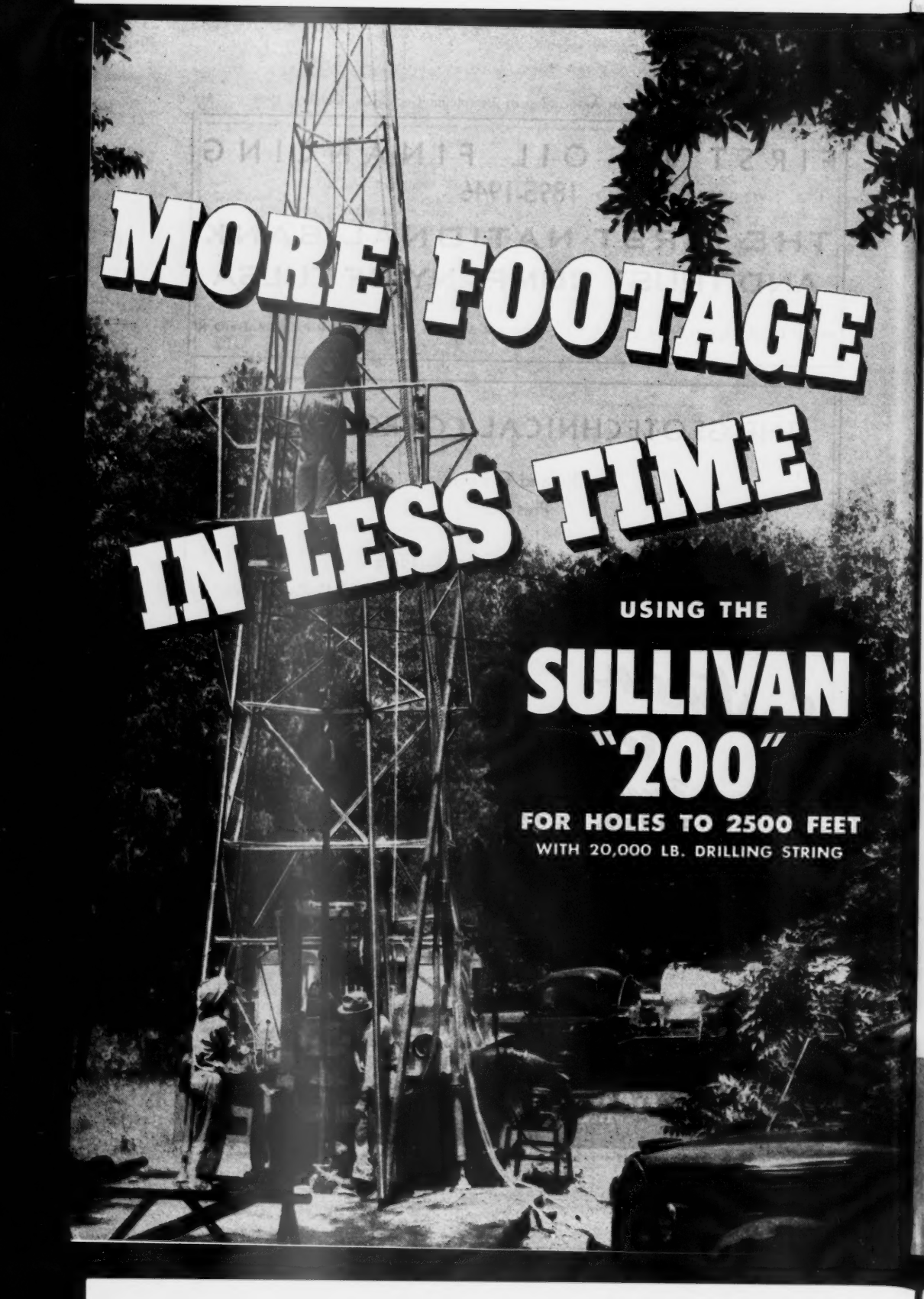
FIRST IN OIL FINANCING
1895-1946
THE FIRST NATIONAL BANK
AND TRUST COMPANY OF TULSA
MEMBER FEDERAL DEPOSIT INSURANCE CORPORATION

THE GEOTECHNICAL CORPORATION
Roland F. Beers
President
1702 Tower Petroleum Building
Telephone L D 101 Dallas, Texas

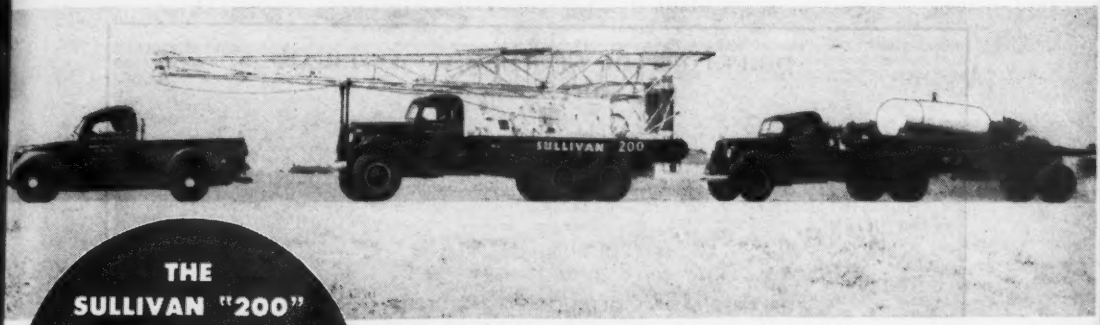
Eastman GETS RESULTS!
Because of . . . MORE THAN 15 YEARS OF
SOUND, PRACTICAL, WORLD-WIDE . . .
EXPERIENCE



EASTMAN OIL WELL SURVEY COMPANY
DALLAS • DENVER • LONG BEACH


MORE FOOTAGE
IN LESS TIME
USING THE
SULLIVAN
"200"
FOR HOLES TO 2500 FEET
WITH 20,000 LB. DRILLING STRING

For Structure Testing, Core Drilling, Electrical Logging
and Shallow Slim-Hole Production.



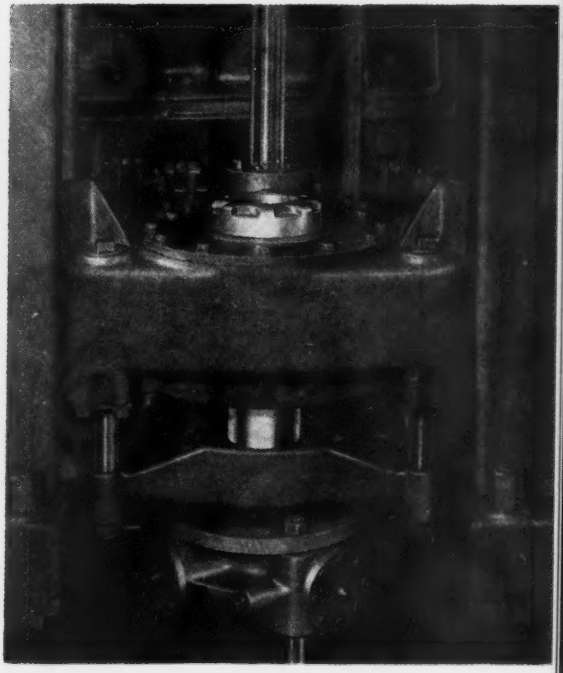
THE SULLIVAN "200" IS *Completely Portable*

A completely portable rig for exploratory drilling . . . that's the remarkable Sullivan "200"—the outstanding rig for high speed drilling at low cost. The entire rig, including the folding two-piece derrick, can be mounted on a truck, trailer, tractor or skids.

Featuring

AUTOMATIC *Hydraulic Chuck*

The Sullivan-developed Automatic Chuck is a key factor in the unsurpassed performance record of the "200" portable drill rig. It serves the triple purpose of rotary table, safety clamp and chuck when drilling without kelly. Besides saving labor, it increases drilling speed, lowers drilling costs and makes a definite contribution to greater safety. Once you see the Sullivan Automatic Chuck in action, you'll wonder how you were ever satisfied with former drilling performance! Write for descriptive bulletin.



Consult a Joy Engineer

SULLIVAN DIVISION

JOY MANUFACTURING CO.

GENERAL OFFICES: HENRY W. OLIVER BUILDING
PITTSBURGH, PA.

W&D 0

DIRECTORY OF GEOLOGICAL MATERIAL IN NORTH AMERICA

J. V. HOWELL AND A. I. LEVORSEN
Tulsa, Oklahoma, and Stanford University, California

List of names and addresses of sources of information needed by the geologist: maps, well data, aerial photographs, geologic publications, books, reports, descriptions, special services, basic data.

Originally published as Part II of the August, 1946, *Bulletin*.
Separate copies in paper covers. 112 pages. Price, 75¢.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

The Annotated
Bibliography of Economic Geology
Vol. XV

Orders are now being taken for the entire volume at $5.00 or for individual numbers at $3.00 each. Volumes I-XIV can still be obtained at $5.00 each.

The number of entries in Vol. XV, No. 1, is 1,079. No. 2 is being printed.

Of these, 266 refer to *petroleum, gas,* etc., and *geophysics.* They cover the world, so far as information is available in war time.

If you wish future numbers sent you promptly, kindly give us a *continuing* order.

An Index of the 10 volumes was issued in May, 1939. Price: $5.00

Economic Geology Publishing Co.
Urbana, Illinois, U.S.A.

THE JOURNAL OF GEOLOGY

a bi-monthly
Edited by
ROLLIN T. CHAMBERLIN

Since 1893 a constant record of the advance of geological science. Articles deal with problems of systematic, theoretical, and fundamental geology. Each article is replete with diagrams, figures, and other illustrations necessary to a full scientific understanding.

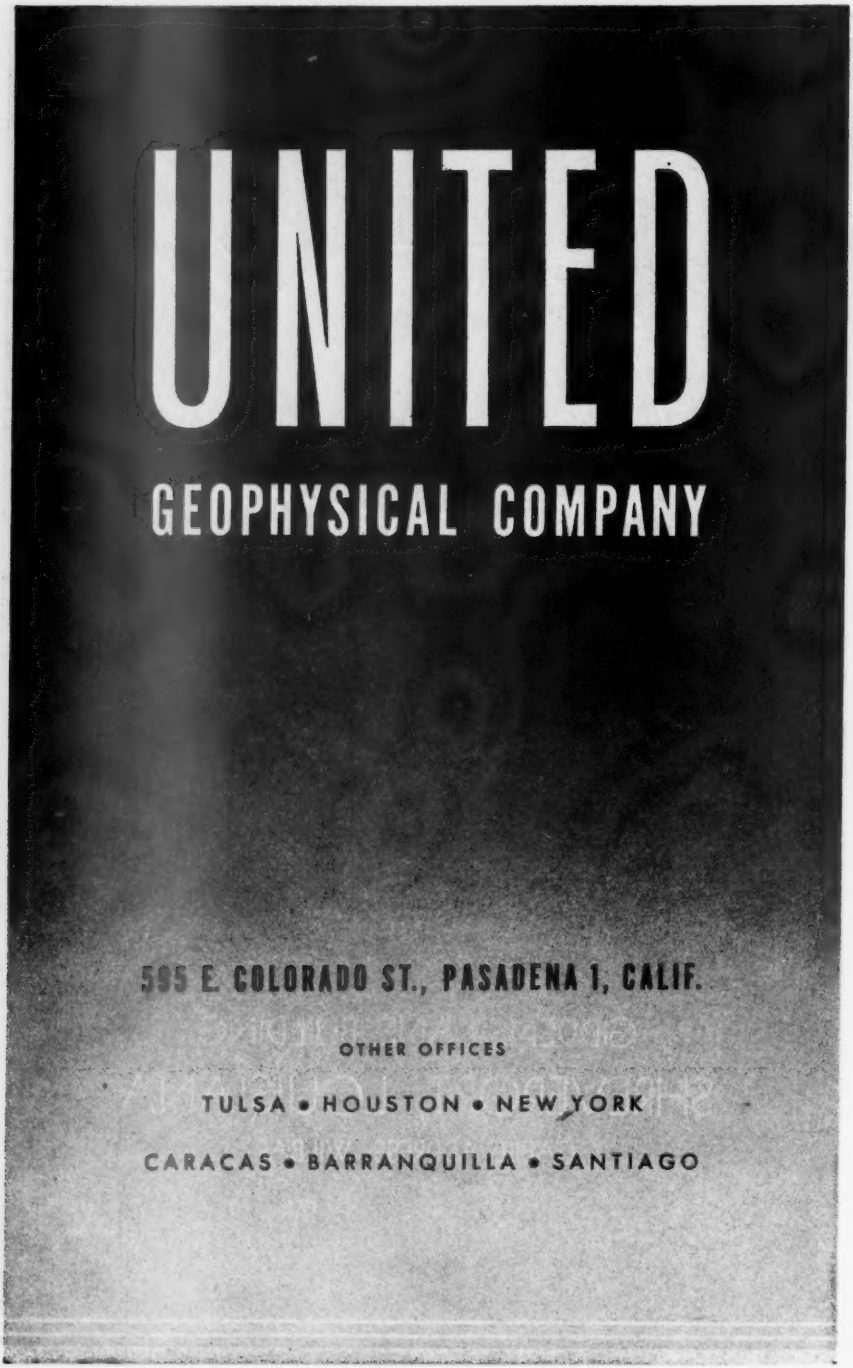
$6.00 a year
$1.25 a single copy
Canadian postage, 24 cents
Foreign postage, 60 cents

THE UNIVERSITY OF CHICAGO PRESS

AERIAL PHOTOGRAPHY
RECONNAISSANCE MOSAICS
PRECISE AERIAL MOSAICS
TOPOGRAPHIC SURVEYS
For information write Department H

AERO SERVICE CORPORATION
Since 1919
PHOTOGRAMMETRIC ENGINEERS
236 E. Courtland Street, Philadelphia 20, Penna.

PETROLEUM AND MINING SURVEYS
WILLIAM M. BARRET, INC.
CONSULTING GEOPHYSICISTS
MAGNETIC AND ELECTRIC METHODS
GIDDENS-LANE BUILDING
SHREVEPORT, LOUISIANA
CABLE ADDRESS: WILBAR

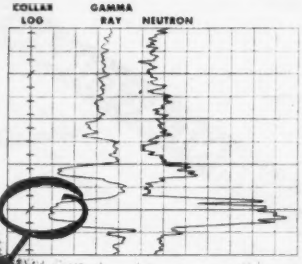

UNITED
GEOPHYSICAL COMPANY
595 E. COLORADO ST., PASADENA 1, CALIF.
OTHER OFFICES
TULSA • HOUSTON • NEW YORK
CARACAS • BARRANQUILLA • SANTIAGO

LANE-WELLS SYSTEM OF COLLAR LOCATION

—ELIMINATES MEASUREMENT VARIABLES

—PERMITS EXACT PERFORATION PLACEMENT

Once casing is set and cemented the relationship between collars and formation is fixed. The collars become accurate bench marks for all subsequent well operations. By means of two simple steps—one electrical and the other mechanical—Lane-Wells uses this fixed relationship to assure accurate placement of gun perforations.



Step #1

The location of collars is recorded electrically with Radioactivity Logging equipment, and each collar is shown on the Log in its fixed relationship to the formation curve. The Collar Log is not charged for when run with a Radioactivity Well Log, but is furnished as an additional feature to provide Oil Well Operators with more useful information about their wells.

Step #2

The reference collar nearest the shooting zone is picked up by the mechanical Collar Locator on the Gun Perforator. This permits accurate perforating even in the thinnest sands without references to bottom or to artificially placed formation markers.

This extreme accuracy saves you time and trouble in...

TESTING OPERATIONS
PLUGBACK OPERATIONS
SQUEEZE CEMENTING
ACIDIZING

"Call Lane-Wells and have the job done right"

Tomorrow's Tools—Today!

LANE-WELLS COMPANY

Los Angeles—Houston—Oklahoma City
General Offices, Export Offices and Plant:
5610 S. Soto St., Los Angeles 11, California
24-HOUR SERVICE 38 BRANCHES

INSTANT ACCURACY
4000
NEW WORLD STANDARDS
of accuracy without lag is an outstanding achievement of the American Paulin System in their new SA series of precision altimeters for all preliminary surveys. Comes in handsome russet leather carrying case.
Write today for the new 1946 general catalog 1-A
AMERICAN PAULIN SYSTEM
1847 SOUTH FLOWER STREET
LOS ANGELES 15, CALIFORNIA
MANUFACTURERS OF PRECISION INSTRUMENTS
Altimeters

KEYSTONE

SEISMIC SURVEYS

KEYSTONE EXPLORATION COMPANY

OFFICES AND LABORATORY

2813 WESTHEIMER ROAD

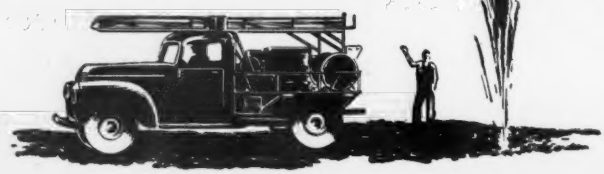
HOUSTON • TEXAS

General
GEOPHYSICAL COMPANY HOUSTON

ACCURATE
GEOPHYSICAL
SURVEYS

•

CORE DRILLING



From grass roots to production Baroid's complete drilling mud service* assures a better, faster job

The combination of Baroid's complete line of drilling mud conditioners and the technical advice of Baroid's experienced field service engineers can solve your mud problems. Laboratory tested and field-proved Baroid products can improve the chances of success on your drilling well. A case typical of thousands is described below.

EXAMPLE

Field: Newhall area, California.

Mud Base: AQUAGEL weighted with BAROID. ANHYDROX added to overcome contaminating effect of anhydrite stringers.

Drilling-in Fluid: IMPERMEX low-water-loss mud, prepared after setting casing.

RESULT

THE WELL CLEANED UP FASTER AND CAME IN BETTER THAN ANY OTHER WELL DRILLED FOR MONTHS IN THE SAME AREA.

PATENT LICENSES unrestricted as to sources of supply of materials, but on royalty bases, will be granted to responsible oil companies and others desiring to practice the subject matter of any and/or all of United States Patents Numbers 1,807,082, 1,991,637, 2,041,086, 2,044,758, 2,064,936, 2,094,316, 2,119,829, 2,214,366; 2,294,877; 2,304,256; 2,387,694; 2,393,165 and further improvements thereof. Applications for Licenses should be made to the Los Angeles office.

BAROID PRODUCTS: ANHYDROX • AQUAGEL • AQUAGEL CEMENT • BAROCO • BAROID • FIBERTEX • IMPERMEX JELFLAKE • MICATEX • SMENTOX • STABILITE • ZEOGEL TESTING EQUIPMENT • BAROID WELL LOGGING SERVICE

*Baroid's complete drilling mud service includes 11 major mud products, production of substantially all drilling mud testing equipment, 3 modern laboratories, 500 points of distribution, 70 field engineers.

BAROID

SALES DIVISION

NATIONAL LEAD COMPANY

BAROID SALES OFFICES: LOS ANGELES 12 • TULSA 3 • HOUSTON 2

Western
GEOPHYSICAL
COMPANY

Combining in one organization the largest and most complete geophysical research facilities in the world together with unexcelled equipment, experienced field crews and proven interpretation technique, Western Geophysical Company meets every requirement of operators desiring a *complete* and well-rounded geophysical service.

Western's seismic and gravity crews are now operating in all parts of the United States and in South America. Western service is available for surveys in any part of the world. Inquiries are invited.

Western GEOPHYSICAL COMPANY

HENRY SALVATORE PRESIDENT

EDISON BLDG., LOS ANGELES 13, CALIF. ★ FIRST NATIONAL BANK BLDG., DALLAS 2, TEXAS

118 COMMERCE ST., NATCHEZ, MISSISSIPPI

Fedralite *Plastic Shot Hole Casing*

IS MAKING MORE TRIPS TO THE FIELD EVERY DAY!

- Light Weight
- Strong-Tough
- Safer
- Factory-Threaded
- More Economical

• In every phase of geophysical shot hole work, Fedralite Plastic Shot Hole Casing means big savings. It's "right" for swamp or prairie locations. And that's why it was quickly accepted by the trade . . . because Fedralite does provide a strong, light weight, trouble-saving, economical shot hole pipe in the field.

Fedralite Plastic Shot Hole Casing is easy to handle at the shot . . . convenient to transport. It provides plenty of strength for jetting and drilling operations. It is smooth-surfaced, with no burrs or sharp edges to injure hands. It is factory threaded with firm, clean, smooth threads to promote faster couplings, tighter joints. Couplings are attached at the factory.

Fedralite Plastic Shot Hole Casing has been continually improved ever since it was introduced. Federal Engineers have followed it into the field, watched it work, checked results, added refinements. That's why today Fedralite Plastic Shot Hole Casing is the best ever made . . . why it provides even faster, more economical shot hole work. That's why, too, it's making more trips to the field every day. Ask a present user about Fedralite Plastic Shot Hole Casing. You can get immediate delivery from Gulf Coast stocks.

LIGHT AS A FEATHER . . . WITH STRENGTH TO SPARE . . . .

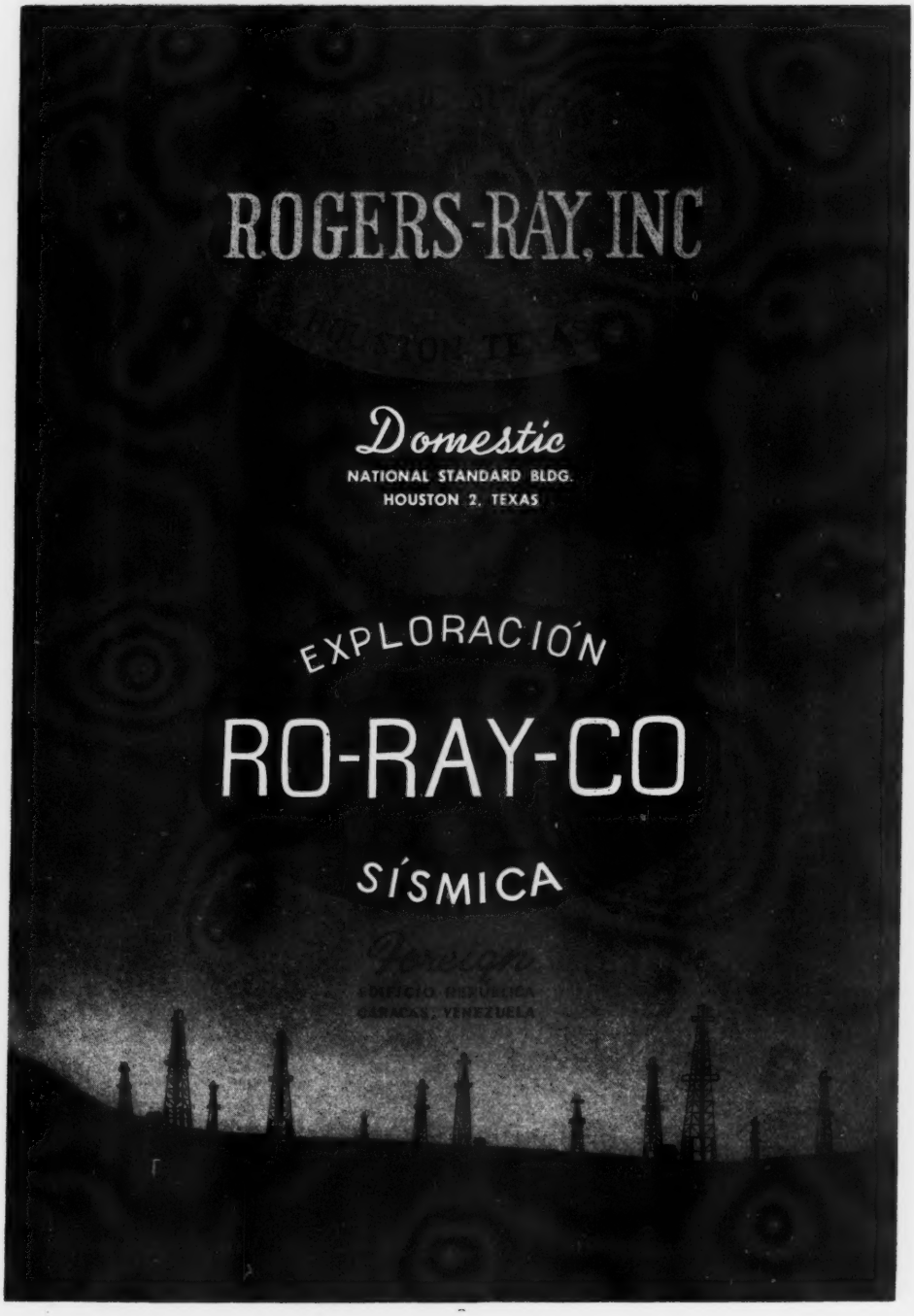
FEDERAL ELECTRIC COMPANY, INC. OF TEXAS

PLASTIC DIVISION

225 North Michigan Avenue — CHICAGO, ILL.

700 Waugh Drive
405 Velasco Street — HOUSTON, TEXAS
2114 Main Street — DALLAS, TEXAS
JENNINGS, LA.
1701 Grand Avenue — KANSAS CITY, MO.
730 St. Charles Street — NEW ORLEANS, LA.

GEOPHYSICAL
ENGINEERING
GRAVITY SURVEYS
CONSULTING
CONTRACTING
Foreign
Domestic


ROGERS-RAY, INC
Domestic
NATIONAL STANDARD BLDG.
HOUSTON 2, TEXAS
EXPLORACIÓN
RO-RAY-CO
SÍSMICA

The yardstick for measuring the value of any seismograph service is accuracy of interpretation . . . a qualification that comes only with long and diversified experience.

SEISMIC EXPLORATIONS, INC. Houston, Texas

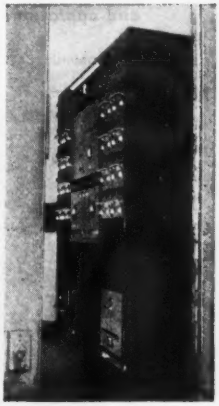
Seismograph Equipment

Manufactured by

NORTH AMERICAN

This equipment as well as the Portable Gravity Meter, other geophysical apparatus and precision equipment is manufactured in our own Laboratories.

REFLECTION SEISMOGRAPH UNITS



This complete 16 cannel, dual recording unit is mounted in a special stainless steel body, having two power driven cable reels, completely wired, tested and ready for field service. Amplifiers have full, automatic amplitude control and complete rejection of 60 cycle power line interference. It has inverse feed back filters, 6 filter settings controlled by selector switch on instrument panel, which makes it possible to obtain any 6 filter curves. Interchangeable plug-in type filter units make it possible to readily change complete system of filter curves. Dual output is available, providing for mixed and unmixed recording simultaneously. Light weight seismometers are furnished with either fluid or electro-magnetic damping.

PORTABLE CABLE REEL

This light-weight reel, designed for use in areas inaccessible by truck, carries 1200 feet of cable and is worn on the back or chest. When laying cable it is worn on the back, the cable unreeling as the operator walks along. When reeling in, it is worn on the chest, and the cable wound on the drum by the crank as the operator walks along. Wide web belting assures comfortable fit. The complete reel weighs only 5 pounds. Weight with 1200 feet of tapered seismograph cable is only 23 pounds. The reel is available with or without cable.

NORTH AMERICAN GEOPHYSICAL COMPANY

Gravity-Magnetic-Seismic Surveys **Geophysical Apparatus**

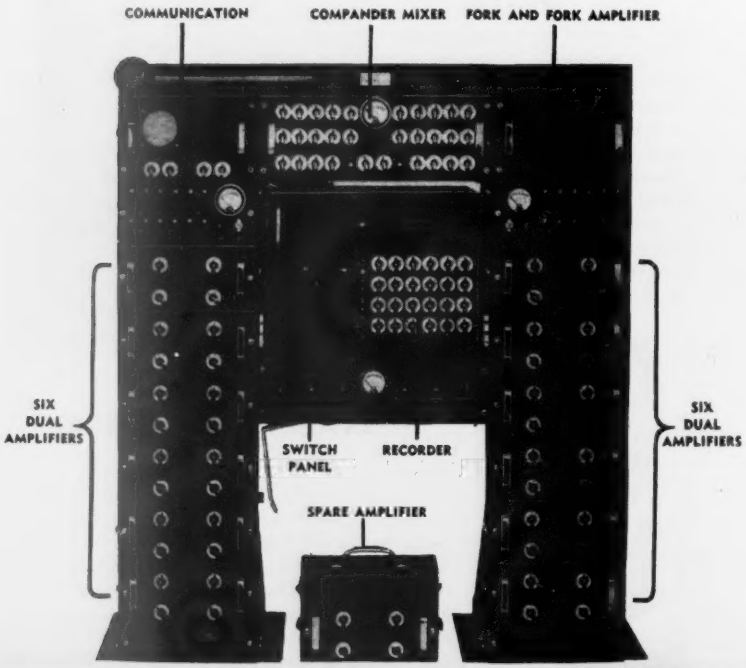
636 Bankers Mortgage Building

Houston 2, Texas

DEPENDABLE *Equipment*

Assures Accurate Surveys for You

Heiland 24 Trace Seismic Equipment is the result of years of operating experience under all field conditions of weather, temperature, humidity, and terrain. Careful research and modern production facilities assure a precision product, sturdy, shock-mounted, with all major components quickly removable by means of plug and receptacle connections for inspection and maintenance. For exceptional accuracy, dependability, and operational ease, use Heiland Seismic Equipment.



For complete information write to:

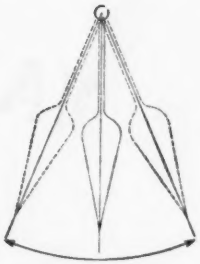
HEILAND Research Corporation

DENVER, COLORADO

What's the object of Using

a Mechanically Operated Intrument

That Can Give a False Record . . . When



THE E-EA-SY-C INCLINOMETER

Always Gives a True Record

6 ways of using the E - C

1. On Measuring Line.
2. On Sand Line.
3. As a Go-Devil and recovered when changing bit.
4. As a Go-Devil and picked up with a core-barrel overshot.
5. Run in with a core-barrel over-shot when picking up a core.
6. Run inside of bailer in cable tool drilling.

YOU don't waste time with the E-C Inclinometer. It records automatically as soon as the plumb bob comes to rest. It's absolutely self-checking. How? Because electrical recording is not possible unless the E-C plumb bob is *standing still.* There is no uncertainty when you use the E-C. No re-checking. No waste of rig time. Faster to run. More economical.

SPERRY-SUN

SPERRY-SUN WELL SURVEYING CO.

Offices: Philadelphia, Pa.; Houston, Corpus Christi, Falfurrias, Marshall, Odessa, Texas; Lafayette, La.; Long Beach, Bakersfield, Calif.; Oklahoma City, Okla.; Casper Wyo.

QUALITY
EXPERIENCE
DEPENDABILITY

* *Quod erat demonstrandum (Which was to be demonstrated)*

The many successful drilling operations which have resulted from Petty geophysical surveys, in fields throughout the world during more than the last two decades, demonstrate the value of our background of broad experience, advanced geophysical equipment, accurate interpretations and expert crews in obtaining authentic subsurface data on which to formulate drilling plans.

PETTY

GEOPHYSICAL ENGINEERING CO.

Seismic — Gravity — Magnetic Surveys

SAN ANTONIO, TEXAS

SOUTHERN

PRECISION SEISMIC SURVEYS

REFLECTION

REFRACTION

•

DATA REANALYSIS

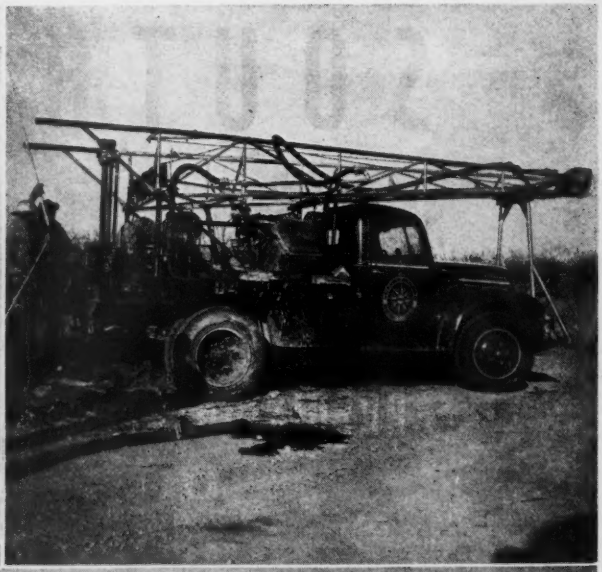
•

SOUTHERN GEOPHYSICAL COMPANY

SIDON HARRIS, PRESIDENT

SINCLAIR BUILDING

FORT WORTH, TEXAS



14 YEARS of continuous improvement . . .

in equipment, methods, and techniques . . . your assurance of profitable results from your geophysical exploration contract with Independent

The founders of Independent were among the early geophysicists to make practical use of the reflection seismograph method of subsurface mapping . . . which resulted in the discovery of many fields which would not have been located by other methods.

Continuous field and laboratory research has been carried on since 1932 and the advantages of new equipment and improved methods are being passed on to Independent's clients in the form of lower costs, more accurate interpretation, and more complete coverage of possible oil producing areas. Your inquiries are invited.

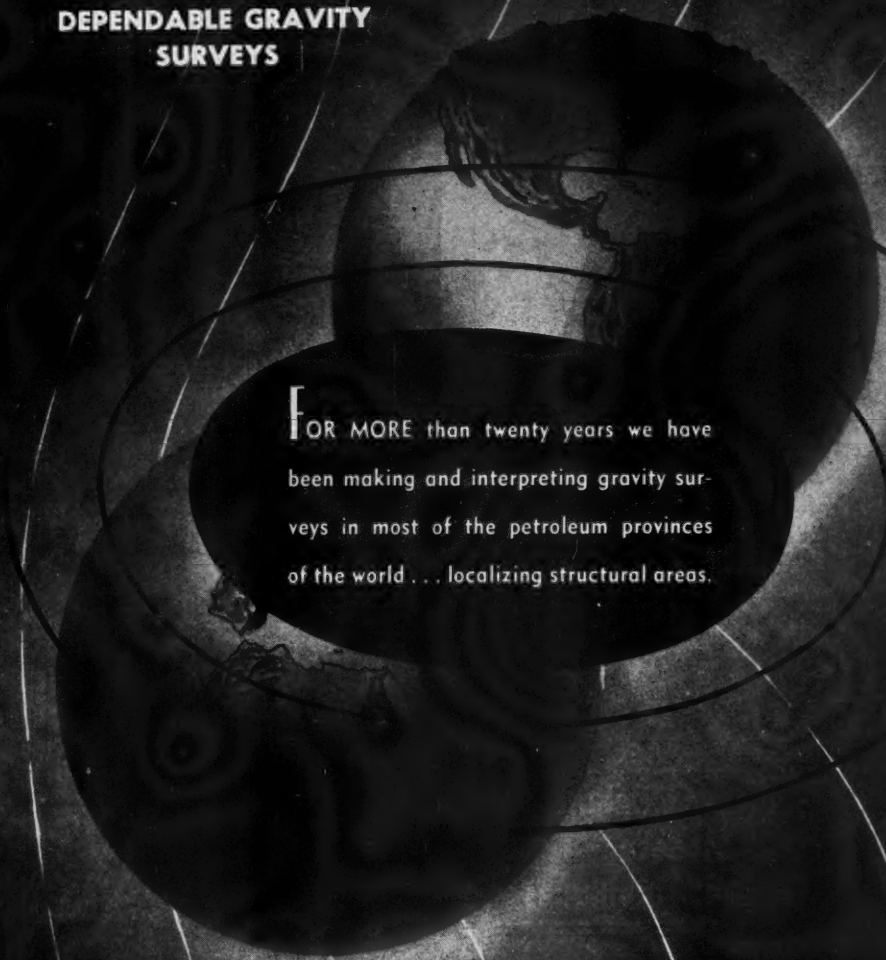
Independent EXPLORATION COMPANY

SEISMOGRAPH
GRAVIMETER
MAGNETOMETER
ESTABLISHED IN 1932

ESPERSON BUILDING **HOUSTON, TEXAS**

GMX

DEPENDABLE GRAVITY SURVEYS



FOR MORE than twenty years we have been making and interpreting gravity surveys in most of the petroleum provinces of the world . . . localizing structural areas.

W. G. SAVILLE · A. C. PAGAN · L. L. NETTLETON

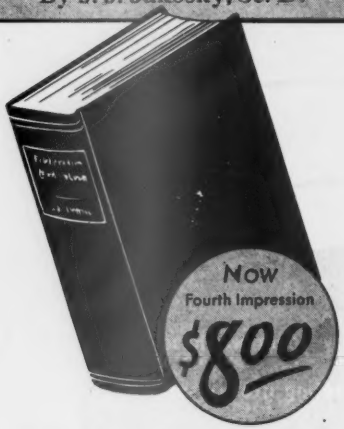
GRAVITY METER EXPLORATION CO.

geophysicists

Esperson Building, Houston, Texas

Exploration Geophysics

By J. J. Jakosky, Sc. D.



Original and important geophysical information for mining and petroleum engineers, supervisors and production men of mining and oil companies, geologists, geophysicists, prospectors, patent attorneys and others. Dr. Jakosky, a nationally known authority in Engineering Education and Geophysical Research, was aided by staff of 32 nationally known geophysicists in compiling this book.

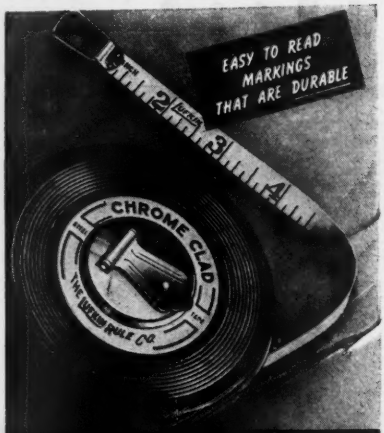
A Complete Compilation of Modern Geophysical Techniques

Describes and illustrates the fundamental theories, detailed descriptions of instruments, equipment and field techniques of the recognized exploratory geophysical methods and applications to problems of economic geology. 430 illustrations; 786 pages, easy to read. Already adopted as textbook by many leading universities. A standard reference book of all times. Sold with privilege of return for full credit.

ORDER YOUR COPY NOW

EXPLORATION GEOPHYSICS

1063 Gayley Ave., Los Angeles 24, Calif.



HIGHEST QUALITY "ANCHOR" CHROME CLAD STEEL TAPE

LUFKIN

SAGINAW, MICHIGAN • New York City

TAPES • RULES • PRECISION TOOLS

STRATIGRAPHIC TYPE OIL FIELDS

Original Articles

By 52 Authors

Edited by A. I. Levorsen

902 pp.
300 illus.
227 references
Bound in blue cloth.
PRICE, $5.50
($4.50 to Members)

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA

Light Flashes at Timed Intervals

for better management and engineering

THE FAIRCHILD HELIOTROPE . . . revolving mirrors . . . a photo-electric cell . . . and electric motor. The Heliotrope is an instrument of wonderful precision. But most important, it is an invaluable new tool for use in establishing triangulation networks; hence it is now an important link in the Fairchild Aerial Survey.

HELIOTROPE MIRRORS revolve in the vertical and horizontal planes at constant speed . . . reflecting sunlight in *every* direction each half-revolution. Hence, with a Heliotrope set up at one control station, light flashes can be intercepted at predictable intervals by Theodolite cross-hairs at *any other* control station. The battery-powered Heliotrope turns on and off automatically, operating unattended for as long as a month at a time.

THE FAIRCHILD ORGANIZATION has played a notable role in the development of the tools and procedures upon which the Modern Aerial Survey is based. Use the Fairchild photogrammetric consultation service when planning a survey.

For Industry, Commerce and Public Works

Since 1920, Fairchild has served clients the world over . . . conducting domestic and expeditionary aerial surveys in the fields of:

Petroleum	Highways	Taxation
Mining	Railroads	Harbors
Geology	Traffic	Flood Control
Forestry	Utilities	City Planning
Water Ways	Pipe Lines	Legal Evidence

Fairchild **AERIAL SURVEYS, INC.**

Photogrammetric Engineers

224 EAST ELEVENTH STREET, LOS ANGELES 15, CALIFORNIA • 21-21 FORTY-FIRST AVENUE, LONG ISLAND CITY 1, N.Y.

KING "FRONT-END" WINCH

for Civilian Willys Jeep

The Model 100 King Winch for Civilian Willys Jeep incorporates the same dependable features that have been used for years on passenger cars and half ton pick-ups in the oil fields all over the orld. These rugged and dependable features together with the latest improvements, such as centralized lubrication and improved drive-shaft suspension, assure a "front-end" winch that will give trouble-free service and long life.

Power for the winch is taken from the front end of the engine crankshaft by means of a solid sheave and a patented sliding clutch using rubber contact blocks to absorb shock and misalignment. This clutch assures a positive drive, eliminates slippage, and can be engaged or disengaged at any time (even under load and with engine idling).

The winch sets directly in the center on front of the Jeep and is easily and safely operated by one man. Recommended cable 150′ 5/16″ 6 x 19 hemp center wire rope.

Weight of complete installation 126 lbs. Speed ratio cable drum to engine 72 to 1.

Sold Exclusively Through Willys Distributors and Dealers

KOENIG IRON WORKS

2214 Washington Ave. HOUSTON 10, TEXAS

C. H. FROST GRAVIMETRIC SURVEYS, INC.

C. H. FROST, *President* JOSEPH A. SHARPE, *Vice-President*

GRAVIMETERS manufactured under license from Standard Oil Development Company

GRAVIMETRIC AND MAGNETIC SURVEYS carefully conducted by competent personnel

GEOLOGIC INTERPRETATION of the results of gravimetric and magnetic surveys

1242 South Boston Avenue Tulsa 3, Oklahoma

MIOCENE STRATIGRAPHY OF CALIFORNIA

By Robert M. Kleinpell

450 pages; 14 line drawings, including a large correlation chart in pocket; 22 full-tone plates of Foraminifera; 18 tables (check lists, and a range chart of 15 pages). Bound in blue cloth; gold stamped; paper jacket: 6 x 9 inches.

PRICE: $5.00, POSTPAID
($4.50 TO A.A.P.G. MEMBERS AND ASSOCIATES)

The American Association of Petroleum Geologists
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

GEOPHYSICAL SURVEYS

UNIVERSAL EXPLORATION COMPANY

2044 Richmond Road

HOUSTON 6, TEXAS

Paul Charrin, Pres. — John Gilmore, V.P. — C. C. Hinson, V.P.

An A.A.P.G. Research Committee Sponsored Report

Released July 15, 1946 as

Colorado School of Mines Quarterly, Vol. 41, No. 3

REVIEW OF PETROLEUM GEOLOGY IN 1945

by

F. M. VAN TUYL AND W. S. LEVINGS

With the cooperation of members of the staffs of the Departments of Geology, Geophysics, and Petroleum Engineering of the Colorado School of Mines

An annual review inaugurated in 1943 by the Department of Publications of the Colorado School of Mines in cooperation with the Research Committee of the American Association of Petroleum Geologists.

Based on information compiled from the literature and from the canvass of leading geologists, geophysicists, and petroleum engineers of the United States and foreign countries.

Features contributions on world exploration and development.

The scope of the work is indicated by the following Table of Contents

Abstract

Introduction

Important Events of the Year
- News Items
- Necrology
- Geologists and the War
- Meetings and Conferences
- Significant Investigations

Advances in Petroleum Geology
- New Developments in the Training of Geologists and Geophysicists
- New Maps and Publications of General Interest
- Contributions to Fundamentals of Petroleum Geology
- Developments in Geophysics
- Progress in Geochemistry and Geobiology
- Developments in Petroleum Enginering

Aerial Photographs

Miscellaneous New and Improved Techniques
- Fluorescence
- Spectroscopy
- Others

World Exploration and Development
- Outstanding Developments in Foreign Countries
- Significant Developments in Petroliferous Provinces of the United States

Production and Reserves
- New Estimates of Domestic and Foreign Reserves of Oil and Gas
- New Procedures and Ideas in Estimating Reserves
- New Ideas on Conservation and Secondary Recovery and Their Influence on Reserves

Trends in Petroleum Geology and Geophysics

Future of the Petroleum Industry

A bibliography of about 1,000 references classified geographically and as to subject will be included

About 150 pages, substantially bound in heavy paper, size 6 x 9 inches

Price $1.50 postpaid if payment accompanies order; otherwise $2.00 postpaid

Send orders early, as the edition will be limited

Mail order with check to

Department of Publications, Colorado School of Mines

Golden, Colorado

ADVANCED EXPLORATION COMPANY

GEOPHYSICAL SURVEYING

Spearpoint of the Petroleum Industry

For ADVANCED
Seismic Equipment and
Technique

CALL ADVECO F-8007

622 FIRST NATIONAL BANK BUILDING
HOUSTON 2, TEXAS

C. W. BOCOCK, III GEO. D. MITCHELL, JR. JAMES L. SAULS, JR.

PRACTICAL PETROLEUM ENGINEERS' HANDBOOK

Reprint of
SECOND EDITION
By JOSEPH ZABA
and
W. T. DOHERTY

This book was written by practical oil men. The tables were compiled so that they can be used by anyone to meet practical field situations without further calculations, and will fit 99% of the conditions under which the average operator is working in the field.

The second edition of the PRACTICAL PETROLEUM ENGINEERS' HANDBOOK has been completely revised and enlarged. Many changes which have been made in the Standard Specifications of the American Petroleum Institute, particularly in pipe specifications, are incorporated in this second edition. Several tables are rearranged and charts enlarged to facilitate their use. Table of Contents and Index are more complete. Also about 90 pages of new formulae, tables, charts and useful information have been added.

This handbook was compiled and published for the purpose of saving the time of operators, engineers, superintendents, foremen and others.

TABLE OF CONTENTS

Chapter I —General Engineering Data
Chapter II —Steam
Chapter III —Power Transmission
Chapter IV —Tubular Goods
Chapter V —Drilling
Chapter VI —Production
Chapter VII —Transportation

Semi-Flexible Fabrikoid Binding, size 6 x 9, 492 Pages. Price: $6.00 Postpaid

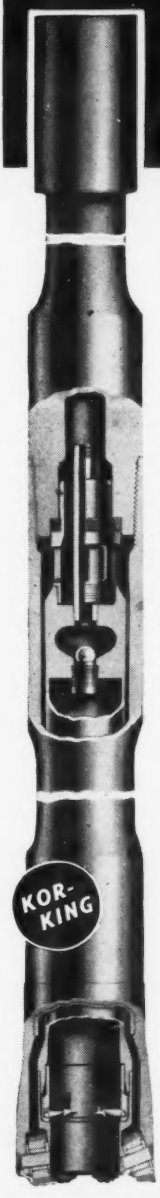
Send Checks to the

GULF PUBLISHING COMPANY

P. O. BOX 2608, HOUSTON, TEXAS

A Complete

CORING SERVICE



REED

Kor-King

CONVENTIONAL TYPE

CORE DRILLS

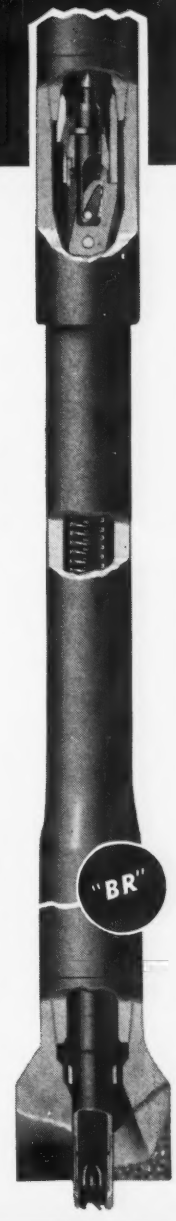
THE SLUSH LUBRICATED, OIL PROOF NEOPRENE BEARING IS A REED KOR-KING FEATURE, PERMITS THE USE OF A FULL FLOATING INNER BARREL, ELIMINATES BEARING TROUBLES AND ASSURES CONSISTENTLY DEPENDABLE PERFORMANCE.

REED

"BR" Wire Line

CORE DRILLS

FOR INTERMITTENT OR CONTINUOUS CORING. THE PROTRUSION REGULATOR SPRING PERMITS RETRACTION OF THE CUTTER HEAD INTO THE DRILLING BIT WHEN THE CUTTER HEAD IS FIRST SET ON BOTTOM AND ASSURES A HIGH PERCENTAGE OF UNCONTAMINATED CORE IN EITHER HARD OR SOFT FORMATIONS.

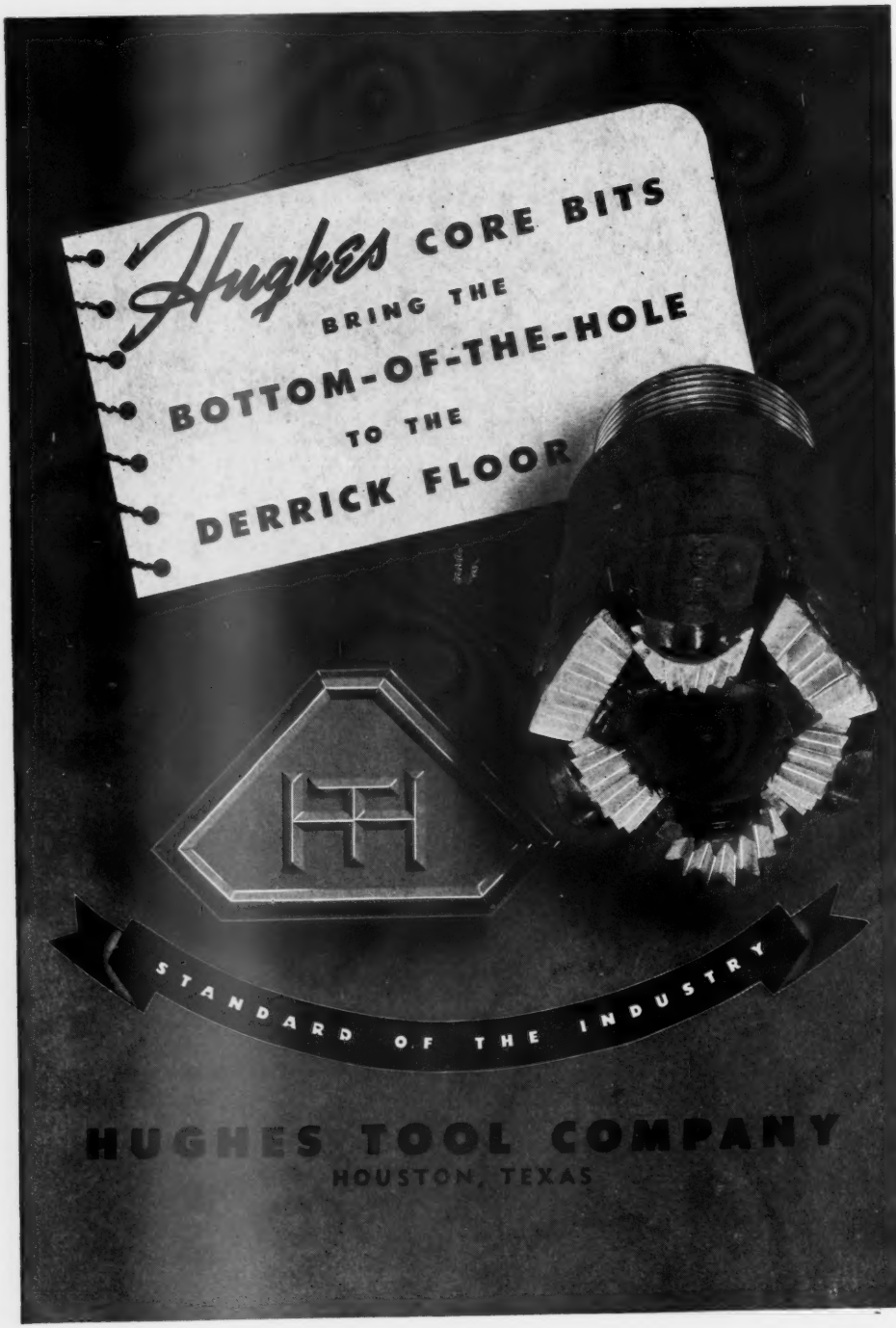


REED ROTARY DRILLING TOOLS

SPEED · ECONOMY · DURABILITY

REED ROLLER BIT COMPANY

P. O. BOX 2119 HOUSTON, TEXAS


Hughes CORE BITS
BRING THE
BOTTOM-OF-THE-HOLE
TO THE
DERRICK FLOOR
STANDARD OF THE INDUSTRY
HUGHES TOOL COMPANY
HOUSTON, TEXAS